

CFD Model of Pit's Cool-tube System for Reducing Effect of Fresh Air & Saving Building Energy Consumption

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ABSTRACT: There is increasing interest in the usage of renewable and new energy sources in the era where we have record high oil price. Among these new energy sources, we have analysed in CFD model, the case which used ground source heat in order to generate required heat for air cooling. The experimentation method allowed heat movement analysis through measurement of room temperature, humidity and air flow simulation. The focus of research area was on method of utilisation of underground pit in cool tube system for piping layout and maintenance. For the ventilation equipment of the "Pit", we have alternated existing system of heat supply for the air conditioning to an energy saving system which recycles normal air exhaust to provide air intake for the compressor room by making it to go through necessary underground heat exchange process. This research has established CFD model on Pit's cool-tube system through heat and air movement simulations, of which data was based on actual measurement and verification.

Keywords: Pit, Cool-tube, CFD(Computational Fluid Dynamics)

NOMENCLATURE

μ_t	Turbulent viscosity[Units]
ρ	Fluid Density [kg/m ³]
v	Velocity Magnitude [m/s]
L	Distance from wall [m]

1. INTRODUCTION

There is growing interest on utilisation of renewable energy source as a solution for energy consumption reduction. Current research is focused on, among many other renewable energy sources, the effective application of ground source heat. Exemplary case it may be for the utilization of underground heat, we recycled air exhaust that went through underground heat exchange to supply air for the compressor room as an alternate energy for

the installation and maintenance of pipe layout of the underground Pit. Such a method will reduce energy demand of air conditioning by using exhaust heat.

As a renewable energy system, cool tube system is essentially varied underground to let in external air flow and pass through the system fixture which will pre-cool or pre-heat the air mass during either summer or winter time to be provided to HVAC system of the building, resulting in reduced cooling or heating load to deal with from the mechanical parts.

There are many precedent cases in Korea and the research led by Mr. Lee Yoon-gu has proposed the ideal balance between architectural designs in relation to its mechanical performance in 2001. This proposal has established the method of architectural planning. This system is about increasing the efficiency of underground

heat source by letting in external air to allow maximum interfaced area with thermal labyrinth in order to reduce air temperature during summer and increase during winter.

In 2005, the research team led by Mr. Lee Sang yup has analysed the effect of energy consumption reduction in consequence of installation of thermal labyrinth in currently undergoing Ehwa University Campus Complex through TRANSYS simulation. The ground layer of the earth has an infinite energy potential with useful application as it has very high tendency for heat storage. Cool tube, ground source heat pump as well as underground duct are examples which incorporated the advantage of ground heat energy.

In 2004, the research team led by Mr. Son Won-Deuk, not only studied system for reduced heating and cooling load, but also analysed how the size, location and installation interval of openings of walls in underground pit structure influence the thermal characteristics as well as behaviour and property of air currents by joint operation of underground heat induced earth tube system and air type collector.

In Japan, a research team led by Mr. Tanaka has analysed the performance of ground source heat exchange in 2004. They the quantity of reduced energy consumption by measuring temperature of a building which correctly employs injection of pre-heated or pre-cooled air during either summer or winter into air handling unit. The depth of the structure of the cool-tube system used in this research was 1.8m below ground level with width of 12m and height of 1.5m constructed in concrete. The air circulation path would elongate between 70m to 110m. The result of this research demonstrated 40% energy consumption reduction due to pre-heated air supply during winter time. .

Also on CFD model research are, a research team led by Mr. Seo Il Hwan, in 2007, has analysed appropriate location of the ventilation equipment in regards to

effectiveness of the ventilation to develop CFD model using warm current model.

The method of current research will be in following orders. First, it would measure actual data of temperature, humidity and velocity of air current within the Pit of the targeted building. Secondly, it would measure exterior temperature and humidity. Thirdly, it would verify the specification and status of currently used equipments. Lastly, based upon measured and verified data, it would establish and verify basic CFD model and propose CFD model. The scope of research is to establish CFD model based on measurement of Cool-tube system within existing Pit especially the heat circulation (temperature) and distribution.

2. Evaluation and measurement of Pit's Cool-tube

2.1 Summary of targeted building

Our target Pit for the evaluation of establishment of CFD model of the cool-tube system of the Pit which utilise underground heat was the one installed in the building (H-commercial store) completed in 2006, located in Iksan city.

The store had 8 storeys above the ground with GFA of 38,600 m² and the cool tube system was installed on the ground floor restaurant for the installation and maintenance of the pipe layout of the kitchen.

The cool-tube system of the Pit induce exterior air current into air intake to compressor once undergone heat exchange process through conduction, convection and radiation. The Pit is 41m deep and 10m wide with area of 562.67 m². It is around 2m high with cubic content of 1,125.34 m³. Currently operational air intake quantity is around 3,600CMH, and air exhaust quantity is around 4,500CMH. The structure is in reinforced concrete. (See Fig. 1)

Since alarm goes off as the internal temperature of compressor room overpass

40°C due to heated oil within the cooling/refrigerating system, a separately installed air conditioning system was adopted to keep 30°C. We would like to evaluate the potential and effectiveness of the cooling system which uses underground heat of the Pit as its status quo requires validation as an alternative of the air conditioning system.

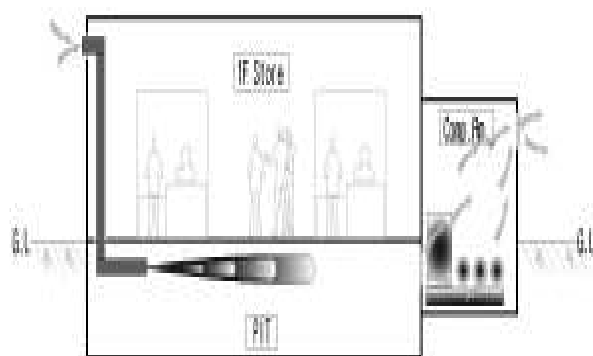


Figure 1: Diagram of Cool tube in the Pit

2.2 Measurement on site

(1) Purpose of measurement

The purpose of on-site verification is to inspect the status of the ventilation within the Pit of the H store as well as of the compressor room which will recycle exhaust air of the Pit into intake air for the comp. room.

In order to check the potentiality of the cool-tube application, we have measured temperature, humidity and air currents for the analysis of current simulation and establishment of CFD model.

(2) Method of measurement

The method of measurement would include tested scope, tested period and testing equipment as described below. The tested scope will be limited to temperature, humidity, and speed of air currents within the internal structure of the Pit. We measured the temperature and humidity of external entrance of the air intake as well as internal structure of the Pit

and also included aforementioned measurement of the compressor room.

Testing period: 1st phase- 10th May, 2008, 14:00 ~ 12th May, 2008 14:00 (48 hrs)
2nd phase 10th, July, 2008 14:00 ~ 12th, July 14:00 (48 hrs), 3rd phase, 11th Dec, 2008, 14:00 ~ 13th 14:00 (48hrs)

The current research was carried out with data obtained during 1st phase.

Testing equipment specs are as followings.

-Thermometer / hygrometer: Thermal Recorder TR-72U, T&D Corp. Japan.

-Current speedometer :Veloci Calc., TSI Inc. USA

-Surface thermometer: Testo 925, Testo AG Germany

Fig. 2 shows interior image of the Pit and Fig. 3 shows the location of the thermometer/hygrometer. The interval of the data storage was set for every 30 seconds for 48 hrs.

The Fig. 4 ~ Fig. 9 shows the measurements taking place in the Pit and compressor room.



Figure 2: Cool tube of the Pit

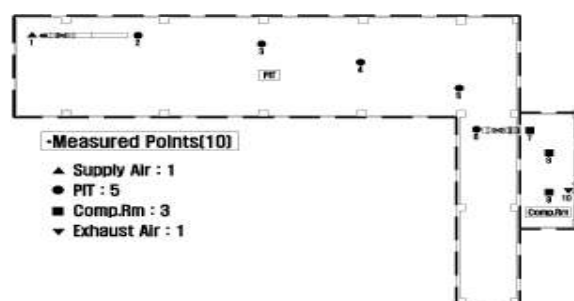


Figure 3: Measuring Points of Temperature & Humidity



Figure 4: Thermal Recorder for Air current



Figure 7: Thermal Recorder for the Comp. room



Figure 5: Thermal Recorder for the Pit



Figure 8: Thermal Recording on the Pit's Surface



Figure 6: Thermal Recorder for the supply air of the Comp. room



Figure 9: Velocity Recorder for the Pit

The specification of currently operated SA/EA fan as well as PAC (Package air conditioning) of research target Pit and Compressor room are shown in Table 1 .

3. The result of analysis of the cool tube in the Pit

The value of temperature, humidity and air current of present research site is as following. Fig. 10 shows external temperature and humidity. Fig. 11 shows temperature/humidity of interior space of the Pit. Fig 12 shows temperature/humidity of the compressor room.

Table I : Index of Equipment

Equipment	Index
Pit's Supply fan	3,600CMH, 20mmAq, 1HP
Combined Pit 's EA Fan & Comp.rm's SA Fan	3,600CMH, 15mmAq, 1HP
Comp.rm's EA Fan	4,000CMH*2ea, 220W*2ea
Comp. rm's PAC	26,000W, 13 kW, 36.1A, R-22

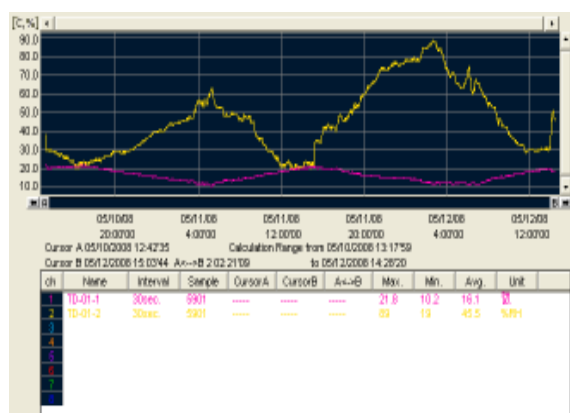


Figure 10: Fresh Air Temperature and Humidity

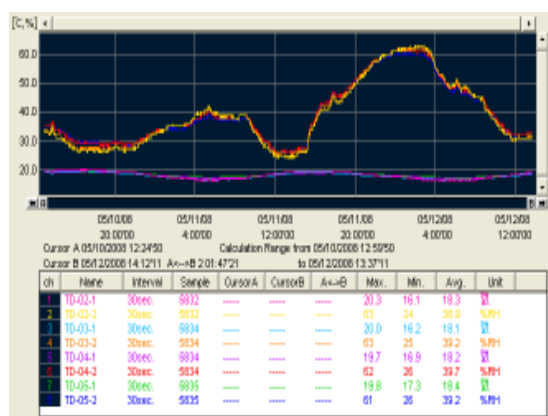


Figure 11: Pit Temperature and Humidity

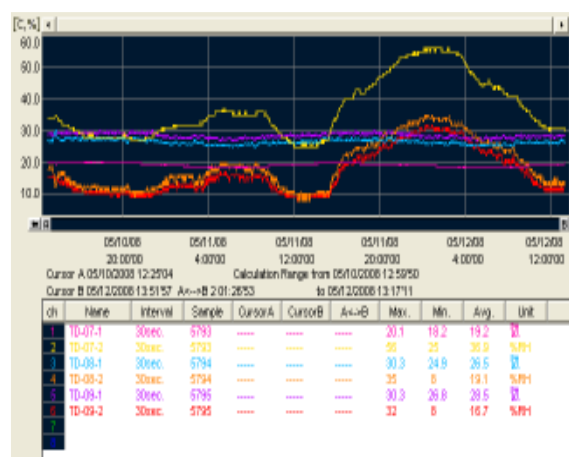


Figure 12 : Comp. rm Temperature and Humidity

Table II shows the synthesized summary of the measurement of resulting temperature, humidity previously shown in Figure10-12 which shows average temperature of exterior air: 16.1°C, Pit: 18.2°C, Comp. room: 24.7°C

Following data were obtained: temperature of the internal floor slab of the Pit: 17.9°C~19.6°C, midway wall surface temperature: 18.1°C~19.3°C, ceiling surface temperature: 18.2°C~20.3°C. This result shows range of temperature of 2.4°C, and the average temperature of the Pit's surface of 18.5°C.

Table II : Temperature Measured (°C)

Section	Point	Max.	Min.	Avg.
Fresh Air	1	21.8	10.2	16.1
Pit	1	20.3	16.1	18.3
	2	20.0	16.2	18.1
	3	19.7	16.9	18.2
	4	19.8	17.3	18.4
Comp.	1	20.1	18.2	19.2
	2	30.3	24.9	26.5
	3	30.3	26.8	28.5

The speed of air current of the compressor room was measured within Pit's lower case of the air intake ventilation grill to its end tip, 7.6 m/s, 3.0 m/s, 1.1 m/s, 0.2 m/s, Comp. Room showed 6.0 m/s, 0.6 m/s, 0.28 m/s for the same location of the temperature measurement.

4. Air current simulation of Pit's Cool-tube

4.1 Indoor Zero-Equation Turbulence Model

In order to interpret and weave air current distribution, consequently to heat transfer experimentation within the space of the Pit, we have utilized various turbulence model of hydro-mechanics for the current research. Also, to interpret the quantity of motion, one should include equation for the hot air current flow as well as that concerning heat transfer by radiation and chemical reactions. In full compliance to above statement, the current research used Airpak 3.0 (Fluent 6.3) and turbulence indoor zero-equation model of CFD program as following. The indoor zero-equation turbulence model was developed specifically for indoor airflow simulations. It addresses the need of HVAC engineers for a simple but reliable turbulence model that can be used with modest desktop computing resources. It uses the following relationship to calculate the turbulent viscosity μ_t :

$$\mu_t = 0.03874 \rho \nu L$$

where ν is the local velocity magnitude, ρ is the fluid density, L is defined as the distance from the nearest wall, and 0.03874 as an empirical constant.

Airpak determines the heat transfer at the boundary surfaces by computing a convective heat transfer coefficient:

$$h = (\mu_{\text{eff}} / \text{Pr}_{\text{eff}}) * (c_p / \Delta x_j)$$

where c_p is the fluid specific heat, Pr_{eff} is the effective Prandtl number, and Δx_j is the

grid spacing adjacent to the wall. μ_{eff} is the effective viscosity, given by

$$\mu_{\text{eff}} = \mu + \mu_t$$

where μ is the viscosity of the fluid.

This model is ideally suited for predicting indoor air flows implicated in natural convection, forced convection, mixed convection, and displacement ventilation

4.2 The conditions of air current simulation

The conditions of air current simulation of our research, based on actual measurement, are as followings (see Table III)

Table III: Boundary Conditions

Section		Condition
Measured	Fresh Air Temp.	21.8°C
	Pit's Wall Avg. Temp.	18.5°C
	Relative Humidity	45.5%
Supply Air Volume		5,000CMH
Cooling load in Comp. rm		76.8 kW (9.6 × 8ea) -May, Rate : 70%
K (Pit's wall)		0.58(W/m²°C) (Code Energy, Korea)

We calculated in equal quantity for both air exhaust and intake to satisfy the input requirements of CFD program. And also set the quantity of the wind in slightly higher value of 5,000CMH, average temperature of Pit's wall surface: 18.5°C, exterior temperature: 21.8°C, in order to verify possible variables. The underground temperature which is temperature of the surface of Pit's wall will depend on the different point in height and therefore, measured top, middle, bottom parts

separately to round up average number to be applied in our research. The data shows, for average the month of May, 5°C higher in comparison to data of KMA at 1.5m, 13.5°C underground in the region of Chun-Ju.

Table IV, and V shows results of air current simulation carried out in 1,000,000 and 260,000cell.

As far as interpretive part of heat transfer of air current simulation is concerned, the formation of cells is very important element to study. This shows the temperature distribution around air exhaust of the Pit (Applies to air intake of compressor room) The Table IV shows, for the case of 1,000,000 cells, the temperature indicates 19.42°C, and 19.39°C for the case of 260,000 cells which demonstrate 0.03°C difference. The above simulation reinforces the idea that the influence of the minuteness of the cells is almost negligible due to large surface are of the Pit.

TableIV: CFD Simulation of the Pit

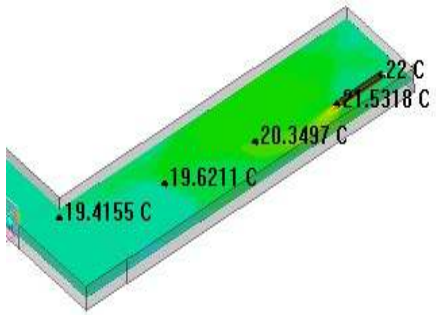
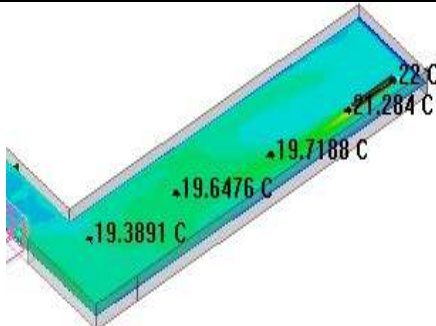
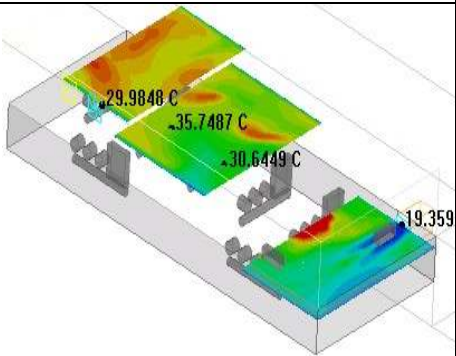
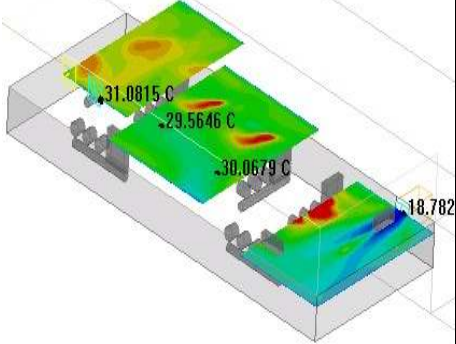
Cell	Temperature
1Mil	
260 Thou sand	

Table V : CFD Simulation of the Comp. rm

Cell	Temperature
1Mil	
260 Thou sand	

Also, Table V shows, for the case of compressor room, the temperature distribution of the air intake area with 1,000,000 cells indicated the temperature of 19.36°C, and 18.78°C for the case of 260,000 cells which demonstrate 0.58°C difference

In slight contrast to the actual measurement of the average temperature of the air intake of the compressor room measured around 19.2°C, the above simulation demonstrated tolerance of 0.42°C ~ +0.22°C.

Therefore, after comparing the actual measurement of the temperature in both Pit' air exhaust and air intake of the compressor room, and measurement obtained through simulation, it showed similar temperature distribution of the case of 260,000 and 1,000,000 cells.

For the future application, in relation to current research data, we will apply 260,000 cells, for the air current simulation of Pit's Cool-tube system.

5. CONCLUSION

This research work verified the effectiveness of the cool-tube system by analysing temperature, humidity and air current of the actually installed case.

Also, we analysed heat transfer through air current simulation and the results are as followings.

Firstly, we measured temperature, humidity and speed of air currents of the cool tube system with pit space during the month of May (spring). The average exterior temperature was 16.1°C, and 18.2°C for the pit, 24.7°C for the compressor room.

Secondly, based on measured data of real case, we have analysed heat transfer through air current simulation and verified our proposed model. The actual measurement of average temperature of air intake of the compressor room is 19.2°C with tolerance of - 0.42°C ~ +0.22°C compared to above simulations.

Thirdly, having verified air current simulation model with formation of 260,000 and 1,000,000 cells, we could get reasonable near values with 260,000 cells.

Lastly, the next step of research would be focused on proposing the best possible pit's cool-tube system after analysis of heat transfer of the air current simulation based on verified CFD model.

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