HEX-4.

As shown in Tables 2 and 3, the preset upper limit temperature for the supply header of the chilled water system and the control of the time length of the forced heat release from the soil heat storage are combined with the variable flow rate control. Furthermore, as shown in Tables 4 and 5, the preset upper limit temperature for the supply header and the control of the time length of the forced heat release from the soil heat storage are combined with the constant flow rate control.

Tables 2　Case study
(The variable flow rate control
×the preset upper limit temperature)

	The outward header preset maximum temperature [℃]	The return header preset temperature [℃]
CaseV-4-2	19 (IO -4)	17 (IO -2)
CaseV-4+0		19 (IO +0)
CaseV-4+2		21 (IO +2)
CaseV-4+4		23 (IO +4)
CaseV-2-2	21 (IO -2)	17 (IO -2)
CaseV-2+0		19 (IO +0)
CsseV-2+2		21 (IO +2)
CaseV-2+4		23 (IO +4)
CaseV+0-2	23　(IO +0)	17 (IO -2)
CaseV+0+0		19 (IO +0)
CaseV+0+2		21 (IO +2)
CaseV+0+4		23 (IO +4)
CaseV+2-2	25 (IO +2)	17 (IO -2)
CaseV+2+0		19 (IO +0)
CaseV+2+2		21 (IO +2)
CaseV+2+4		23 (IO +4)
CaseV+4-2	27 (IO +4)	17 (IO -2)
CaseV+4+0		19 (IO +0)
CaseV+4+2		21 (IO +2)
CaseV+4+4		23 (IO +4)

IO: Initial operation

Tables 3　Case study
(The variable flow rate control
×the forced heat release)

	The outward header preset maximum temperature [℃]	The forced heat release　hours
CaseV-4　S	19 (IO -4)	S　(9:30～16:30)
CaseV-4　M		M　(8:25～17:30)
CaseV-4　L		L　(8:00～18:30)
CaseV-2　S	21 (IO -2)	S　(9:30～16:30)
CaseV-2　M		M　(8:25～17:30)
CsseV-2　L		L　(8:00～18:30)
CaseV+0　S	23　(IO +0)	S　(9:30～16:30)
CaseV+0　M		M　(8:25～17:30)
CaseV+0　L		L　(8:00～18:30)
CaseV+2　S	25 (IO +2)	S　(9:30～16:30)
CaseV+2　M		M　(8:25～17:30)
CaseV+2　L		L　(8:00～18:30)
CaseV+4　S	27 (IO +4)	S　(9:30～16:30)
CaseV+4　M		M　(8:25～17:30)
CaseV+4　L		L　(8:00～18:30)

S;Short
M: Medium
L: Long

Tables 4　Case study
(The constant flow rate control
×the preset upper limit temperature

	The variable flow rate [㎥/h]	The return header set temperature [℃]
CaseC-6-2	8　(CO -6)	17 (IO -2)
CaseC-6+0		19 (IO +0)
CaseC-6+2		21 (IO +2)
CaseC-6+4		23 (IO +4)
CaseC-3-2	11　(CO -3)	17 (IO -2)
CaseC-3+0		19 (IO +0)
CsseC-3+2		21 (IO +2)
CaseC-3+4		23 (IO +4)
CaseC+0-2	14　(CO +0)	17 (IO -2)
CaseC+0+0		19 (IO +0)
CaseC+0+2		21 (IO +2)
CaseC+0+4		23 (IO +4)
CaseC+3-2	17　(CO +3)	17 (IO -2)
CaseC+3+0		19 (IO +0)
CaseC+3+2		21 (IO +2)
CaseC+3+4		23 (IO +4)
CaseC+6-2	20　(CO +6)	17 (IO -2)
CaseC+6+0		19 (IO +0)
CaseC+6+2		21 (IO +2)
CaseC+6+4		23 (IO +4)

IO: Initial operation
CO: Current operation

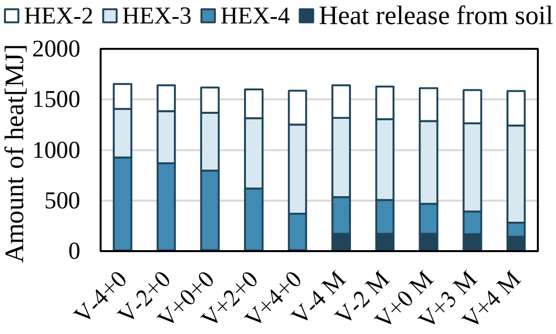
Tables 5　Case study
(The constant flow rate control
×the forced heat release)

	The variable flow rate [㎥/h]	The forced　heat release hours
CaseC-6　S	8　(CO -6)	S　(9:30～16:30)
CaseC-6　M		M　(8:25～17:30)
CaseC-6　L		L　(8:00～18:30)
CaseC-3　S	11　(CO -3)	S　(9:30～16:30)
CaseC-3　M		M　(8:25～17:30)
CaseC-3　L		L　(8:00～18:30)
CaseC+0　S	14　(CO +0)	S　(9:30～16:30)
CaseC+0　M		M　(8:25～17:30)
CaseC+0　L		L　(8:00～18:30)
CaseC+3　S	17　(CO +3)	S　(9:30～16:30)
CaseC+3　M		M　(8:25～17:30)
CaseC+3　L		L　(8:00～18:30)
CaseC+6　S	20　(CO +6)	S　(9:30～16:30)
CaseC+6　M		M　(8:25～17:30)
CaseC+6　L		L　(8:00～18:30)

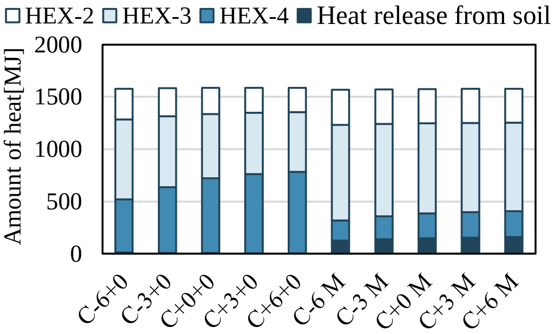
S;Short
M: Medium
L: Long

The room temperature among the calculated values achieves the preset room temperature (28℃) in all cases, although the temperature of the water supplied from the soil heat storage differs in every case.

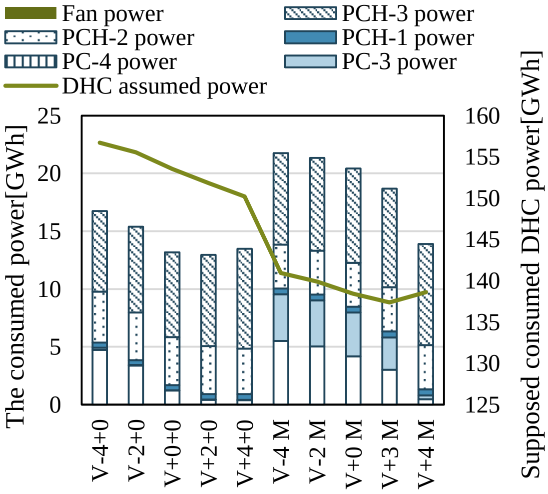
The cases where only the chilled water system secondary side flow rate preset value (return header preset temperature and flow rate) was changed from the conventional operation were compared. Figs. 7 and 8 show the heat release from the soil heat storage and the heat exchange amount of the heat exchanger. In the case of variable flow control, if the return header preset temperature is made lower, the flow rate increases. Depending upon the increase of the flow rate, the heat exchange amount of the chilled water coil increases and the received amount of the heat from DHC by the hot and chilled water system decreases. Although the smaller the chilled water system secondary side flow rate is, the larger the difference in the temperature between inlet and outlet becomes, but because the increase in the flow rate is larger, the heat release amount increases. If the forced heat release time length is preset, the heat release amount is larger in the case of variable flow rate than in the case constant flow rate. This is because when the load is large, the flow rate substantially increases. Figs. 9 and 10 show the integrated consumed power and supposed consumed DHC power. The supposed consumed DHC power is obtained by the system COP of DHC being supposed to be 3.2 and the amount of heat received from DHC being divided by 3.2. The smaller the chilled water system secondary side flow rate is, the more the amount of heat processing of the hot and chilled water system increases and the flow rate increases, and as a result, the amount of power consumption of the pump of the hot and chilled system increases. If the heat release amount from the soil heat storage increases, the supposed consumed DHC power increases. The more the heat release amount from soil heat storage increases, the more the supposed consumed DHC power decreases.



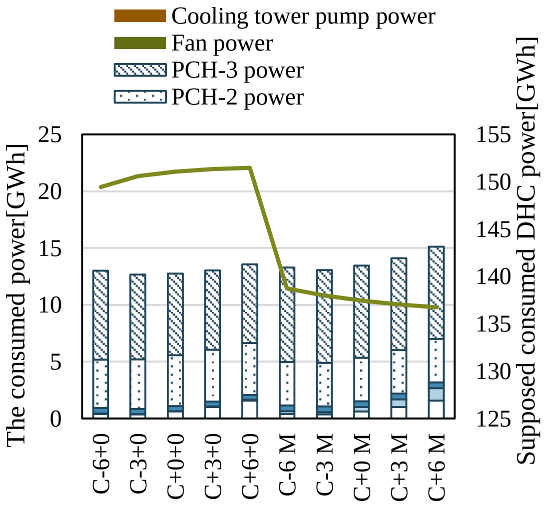
Figs. 7 The heat release from the soil heat storage and the heat exchange amount of the heat exchanger (The variable flow rate



Figs. 8 The heat release from the soil heat storage and the heat exchange amount of the heat exchanger (The constant flow rate

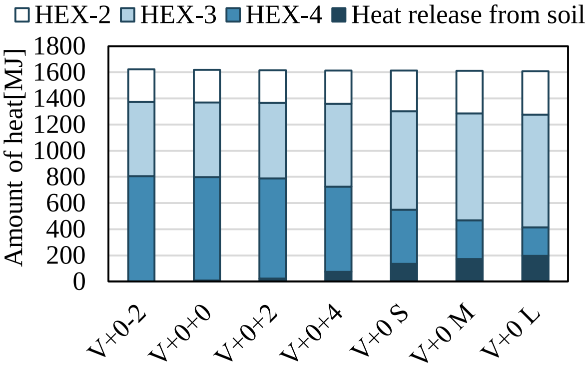


Figs. 9 The integrated consumed power and supposed consumed DHC power (The variable flow rate control)

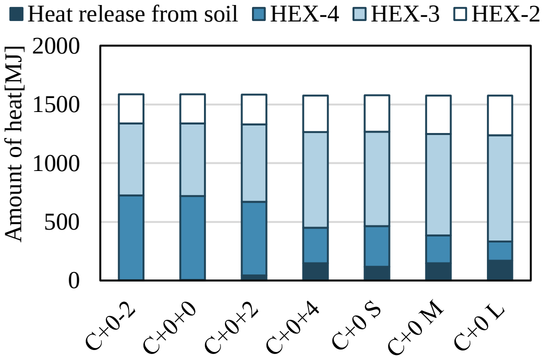


Figs. 10 The integrated consumed power and supposed consumed DHC power (The constant flow rate control)

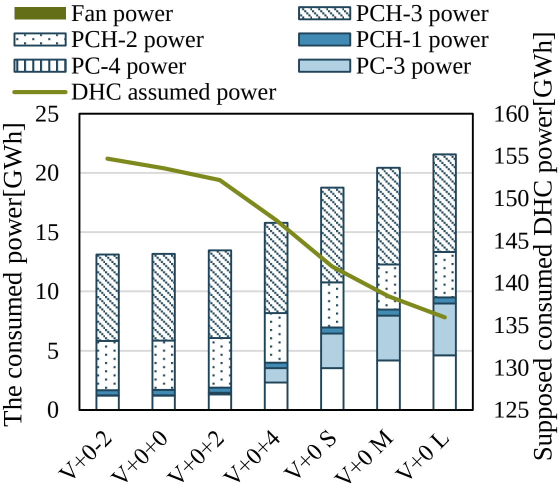
The cases where the DHC switching control (the preset upper limit temperature for supply header and forced heat release time length) exclusively was changed from the conventional operation were compared. The longer the time length of the forced heat release of the soil heat storage (preset upper limit temperature 23℃ for supply header or the time length of forced release of 8:00-18:30), the more the amount of heat release of the soil heat storage increases. Figs. 11 and 12 show the heat release amount of the soil heat storage and the heat exchange amount of the heat exchanger. Figs. 13 and 14 show the integrated consumed power and supposed consumed DHC power. Because the flow rate of the variable flow rate is larger than that of the constant flow rate, the consumed power of the pump of the chilled water system is larger. The longer the time of heat release from the soil is, the more the consumed power by the chilled water pump increases. This is because the high temperature of the atmosphere in the inlet and outlet of the chilled water system coil was kept longer and as a result, the flow rate of the hot and chilled water system increased.



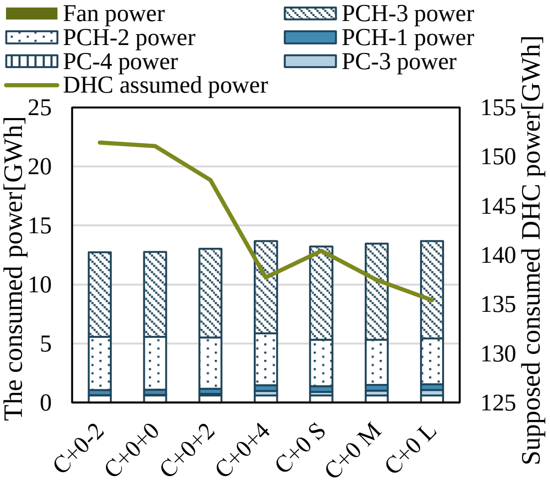
Figs. 11 The heat release from the soil heat storage and the heat exchange amount of the heat exchanger (The variable flow rate



Figs. 12 The heat release from the soil heat storage and the heat exchange amount of the heat exchanger (The constant flow rate



Figs. 13 The integrated consumed power and supposed consumed DHC power (The variable flow rate control)



Figs. 14 The integrated consumed power and supposed consumed DHC power (The constant flow rate control)

Regarding all 52 cases, Fig. 15 shows the relationship between the heat release amount from the soil heat storage and the consumed power. Fig. 16 shows the relationship between the time length of the heat release from the soil heat storage and the heat release amount. In Figs. 15 and 16, the same sign is used for the case where the secondary side flow preset value is the same. The larger the heat release amount is, the more the received amount of heat from DHC decreases and the consumed power also increases. The longer the heat release time from the soil heat storage is, the larger the amount of heat release becomes. The relationship between the chilled water system average secondary side flow rate in August and the heat release volume is shown in Fig. 17, the relationship between the time length of heat release from the soil heat storage and the consumed power is shown in Fig. 18 and the relationship between the chilled water system average secondary side flow rate in August and the consumed power is shown in Fig. 19. In the case where control is implemented by the preset upper limit temperature for the supply header, the smaller the flow rate is, the more the heat release amount from the soil heat storage increases. The smaller the flow rate is, the larger the difference in temperature between the inlet and outlet becomes and the more the temperatures of the inlet and outlet of the soil heat storage decrease, so that the amount of heat that increases more than the preset upper limit temperature for the supply header and is received from DHC through HEX becoming small. In the case where the time length of the forced heat release is preset, the larger the flow rate is, the more the heat release increases. This is because, although the larger the flow rate is, the smaller the difference in the temperature between the inlet and outlet of the soil heat storage becomes, the amount of change in the temperature is small. However, because if the flow rate increases, the consumed power of the pump also increases, it is not effective. In the case where the time length of forced heat release is set by constant flow rate (C-6 L、C-3 L、C+0 L、C+3 L、C+6 L), the most energy saving case is C+0+4 from the balance of the increase of power consumed by the chilled water system pump caused by the increase in flow rate and the decrease in the received amount of heat from DHC. In the case of C-3+4, the heat release is largest and the consumed power is smallest. Although the difference in temperature between the inlet and outlet of the soil heat storage is larger in the case of C-6+4 where the flow rate is small, this is because it is small compared with the difference in flow rate.

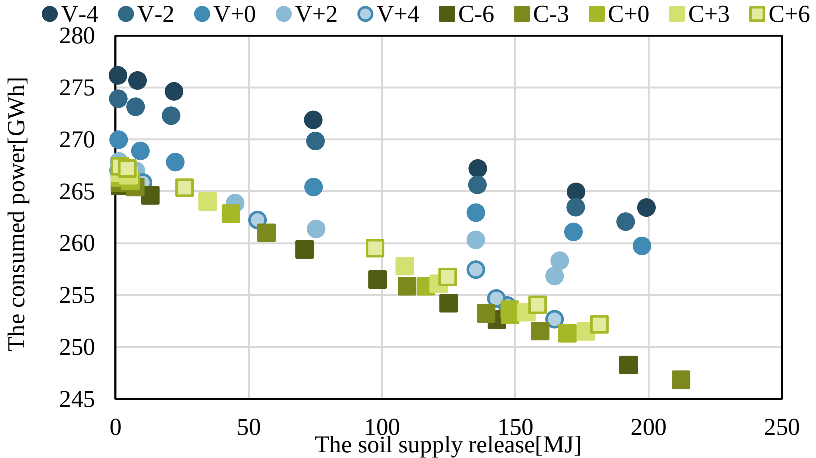


Fig. 15 The relationship between the heat release amount from the soil heat storage and the consumed power

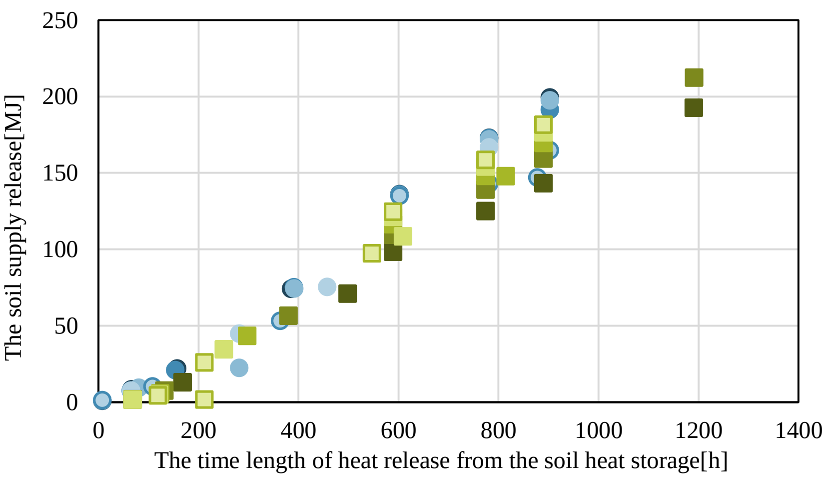


Fig. 16 The relationship between the time length of the heat release from the soil heat storage and the heat release amount

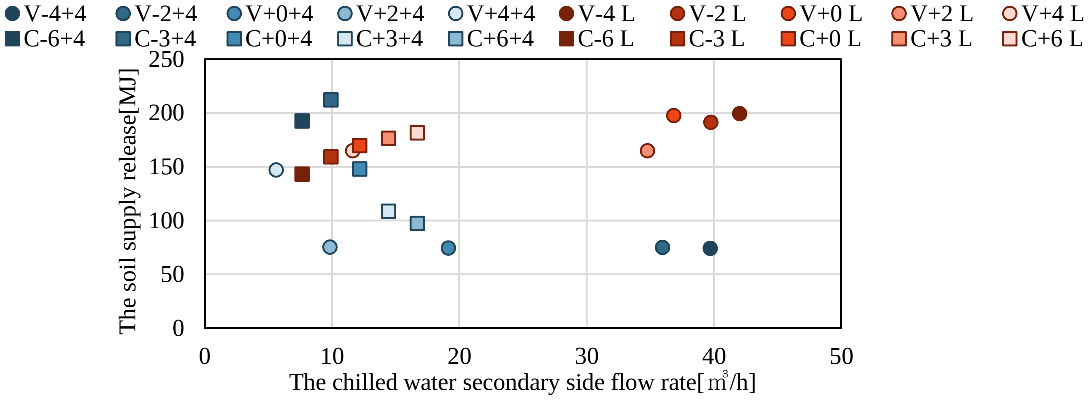


Fig. 17 The relationship between the chilled water system average secondary side flow rate in August from the soil heat storage

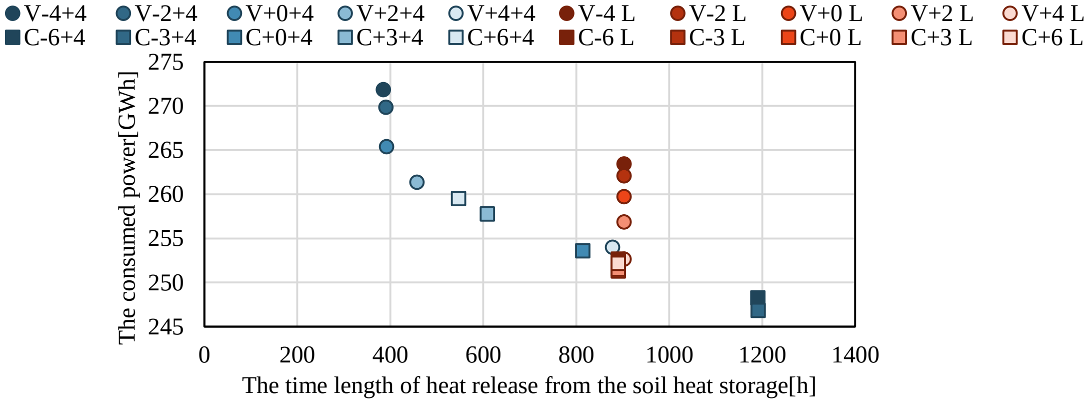


Fig. 18 The relationship between the time length of heat release from the soil heat storage and the consumed power

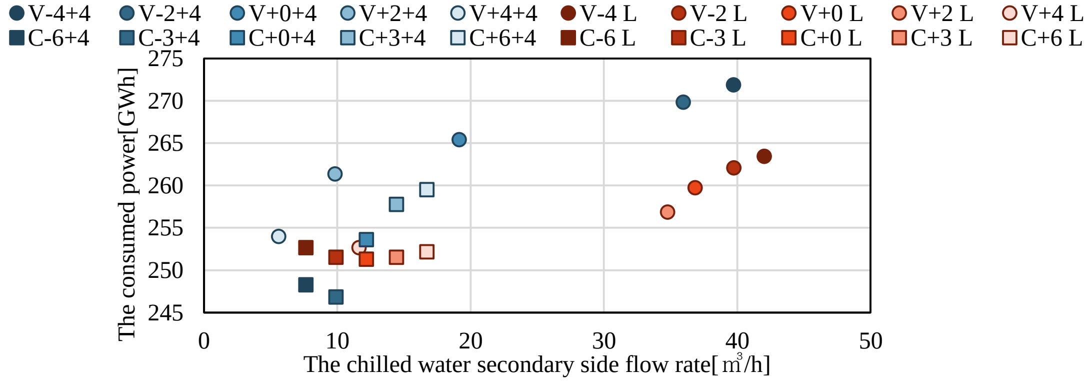


Fig. 19 The relationship between the chilled water system average secondary side flow rate in August and the consumed power

5. Conclusion

In this report, a whole air-conditioning system was replicated with the secondary side model in addition to the simulation model that had been developed. With this method, it became possible to more precisely replicate the secondary side behaviors at the time of heat release from the soil heat storage. A discussion was implemented on the operation methods of the soil heat storage system using the developed model. As a result, it was revealed that it is necessary to increase the heat release in order to make the soil heat storage more energy efficient. It was clarified that for this purpose, it is necessary to make the time length of the heat release from the soil heat storage longer and preset the flow rate with the differences in the temperature and flow rate between the inlet and outlet taken into consideration.

References

1) Shinya IMAI : Measurement Survey of the Internal Heat Generation in Commercial Buildings（part5）Proposal on how to set up internal heat generation, The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan,pp241~pp244, September,2013