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VIII

GROUND SOURCE HEAT PUMP SYSTEM FOR A SHOPING CENTER IN ISTANBUL WITH 18.327 METERS OF GROUND DRILLING

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SUMMARY

For the new Metro shopping center project in Istanbul Turkey, Ground Source Heat Pump system was selected as part of a Green Building concept. The design that started in the late 2005, resulted in the starting of the ground work application in mid 2006. Initial calculations, selections and sizing of the system, design of the ground part, application of the vertical drills and the piping of the system has been done till June 2007, resulting in 18,300 meters of vertical drill work that is the biggest application in Europe excluding the Nordic countries, or one of the biggest 5 applications including Nordic countries.

The complete Ground work and the supply of equipment has been done by FORM company. The system will be explained from design till application and testing, with various pictures from the job site. The difficulties and the challenges and their solutions will also be explained and shown. The startup of the system that was done in August 2007.

INTRODUCTION

Investors of the land in Istanbul, Umraniye area, which is a very fast developing part on the highway with several shopping areas and a very large amount of newly built homes, had decided to build a shopping center unitizing Green energy concepts. One of the possibilities was Ground source heat pump application and after several discussions with the mechanical works designer and the architect company it was decided to explore the idea more deeply. The first discussions and design calculations started in late 2005.

Fig.1 Metro Shopping center in Istanbul

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1. PROJECT DESIGN

The upper part of the area was chosen for a possible ground drilling site and 2 sample drills were made to understand the details of the ground. At the same time utilizing the capacity loads calculated by the mechanical designer, possible drilling quantity scenarios were beginning to be created. The beginning calculation of the loads were 2,380 kw for cooling and 1,227 kw for heating. The loads and the ground details were sent to the USA company that had offered technical help in sizing the ground side of the job.

The first report was created in USA on November 2005 with 9 alternative selections, according to the loads given. The table included possible changes according to number of drills, pipe size, pipe length per drill, distance between drills, size of cooling tower and its frequency of use in different periods. Later several other alternatives were added and the list of scenarios were increased to 14.

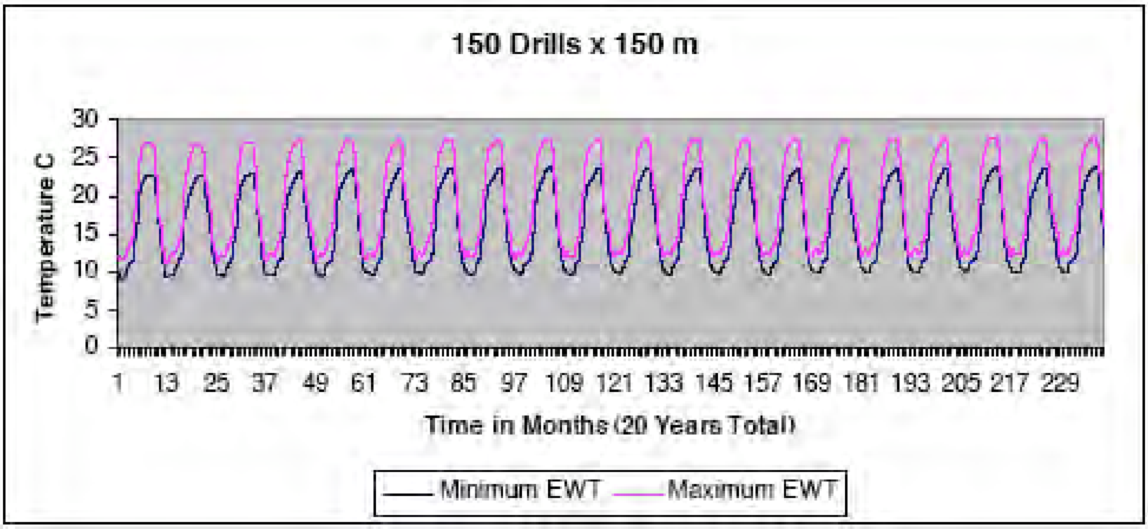
GROUND SIDE ALTERNATIVES

Peak cooling load : 2,380 kW
Peak heating load : 1,227 kW
Total cooling load : 2,871,330 kWhr
Total heating load : 367,950 kWhr

	Nr. of Borehole	Borehole depth	Pipe Diameter	Borehole spacing	Cooling tower	Winter working	Min. Loop Outlet Temp.	Max. Loop Outlet Temp.
Alt. 1	240 pcs.	150 m	1"	6 m	No	-	14.78 °C	66.17 °C
Alt. 2	240 pcs.	150 m	1"	10 m	No	-	14.79 °C	44.68 °C
Alt. 3	240 pcs.	150 m	1"	6 m	Yes - %100	Yes	14.61 °C	17.86 °C
Alt. 4	240 pcs.	150 m	1"	6 m	Yes - %50	Yes	11.82 °C	22.75 °C
Alt. 5	240 pcs.	150 m	1"	6 m	Yes - %25	Yes	13.94 °C	40.76 °C
Alt. 6	200 pcs.	150 m	1"	6 m	Yes - %25	Yes	11.83 °C	20.23 °C
Alt. 7	200 pcs.	150 m	1"	10 m	Yes - %25	Yes	11.84 °C	20.4 °C
Alt. 8	300 pcs.	100 m	1"	10 m	Yes - %25	Yes	11.93 °C	20.32 °C
Alt. 9	200 pcs.	150 m	1 1/4"	6 m	Yes - %25	Yes	11.97 °C	20.1 °C
Alt. 10	200 pcs.	150 m	1 1/4"	6 m	Yes - %50	Yes	10.89 °C	24.12 °C
Alt. 11	150 pcs.	150 m	1 1/4"	6 m	Yes - %50	Yes	9.06 °C	27.47 °C
Alt. 12	100 pcs.	150 m	1 1/4"	6 m	Yes - %50	Yes	5.22 °C	34.79 °C
Alt. 13	100 pcs.	150 m	1 1/4"	6 m	Yes - %50	(Summer+March+Apr+May)	9.05 °C	38.75 °C
Alt. 14	100 pcs.	150 m	1 1/4"	6 m	Yes - %75	(Summer+Apr+May)	9.47 °C	26.83 °C

The reports were done using the available heating cooling loads, the ground sample drill results and weather conditions of Istanbul. The idea in the reports were to calculate a 20 year working condition simulation with the data, to see the result of the ground temperatures in the end of this period. From the table it is easy to see that due to the low heating loads, the alternatives differ very little in the low side of the ground water temperatures. But due to the large cooling loads, the high side ground temperatures range from 17c to 68c! In order not to increase the initial cost the design was decided to be done at equal capacity loads of heating and cooling. This was also allowing the ground to be equally charged each season. This required the use of a cooling tower to balance the rest of the cooling load. It was also seen that if the cooling tower was to be used in the end of winter to further cool the ground or at certain nights to charge the ground when outdoor and ground conditions were suitable, the balance was better.

So after a detailed study of the alternatives, for a cooling load of 2,380 kw and heating load of 1,227 kw, it was decided to do 150 drills of 150 meters each, total 22,500 meters, with 1.1/4” pipes, 6 meters from each other and a cooling tower working in both summer and winter. The study showed that with these values it was possible to stay inside a 9.06 c to 27.46 c ground temperature swing for a 20 year period calculation. A detailed graph of the study showing the constant increase and decrease in temperatures seasonally is below.



With this data, the mechanical project designer made return of investment calculations. A comparison table with a classical system, having air cooled chillers, 4 pipe fan coils and a boiler was made with first and running cost calculations. This was compared with a ground source heat pump system design according to above selections. The results showed that the ground source heat pump system was more expensive as first cost but had better running costs as expected. The results showed that in about 9 years the additional cost was recovered and the system had a profit from then on.

According to this data, in the beginning of 2006, the system was decided to be done as ground source heat pump and the designer continued to work on actual unit selections and details of the complete design.

2. CONTRACTING THE WORKS

In the next 6 months the mechanical side of the contract was not given to a company due to several problems but at the same time the construction of the building continued. There were several discussions in terms of where to place the drills, including under or next to the building. Mid of 2006 the building contractor had finished half of the ground work of the foundations of the building and the original place where the ground sample drills were done were already closed.

The contract for the drills was finally cleared but the place to apply them was the opposite side of the area.

3. PROJECT COMPLETION

After the first several drills, it was understood that the new area was not suitable for Air type drills and Mud type drilling had to be used. The first 30 meters of the ground was very weak and required to be held from collapsing by placing a metal pipe. Still the rest of the ground also collapsed at different levels, requiring much longer time to complete the 150 meters required. This required a much longer time per drill than anticipated before and the building contractor had to finish the foundations in a limited time as well.

Fig.2-3 Special collector

With this new position of time problem and urgency, it was decided that the drills had to have a time limit resulting in stopping them at different levels according to the ground at that exact position. This would result in different lengths of drills! This also created a new problem to be solved, balancing of the ground pipes which were going to be un even.

To solve this problem a special collector was ordered from a manufacturer in Germany, allowing each line to be balanced through valves and water flow gauges. This also allowed the system to be much more flexible as each drill piping could be also completely closed in case of a problem and flushing was easier to do at each collector separately.

The drill work was started with 2 trucks and increased up to 6 trucks at the same time, changing due to the allowable space at the work place.



Fig.4 Drilling Fig.5-6 Inserting the pipes

The pipes inserted into the drills were PN16 - SDR11, PE type, pressure tested vertical loop pipe imported from Switzerland, with a third pipe to be used for the grouting process. The drills were spaced about 6 meters from each other as planned and were checked for correct placement in order not to cross with the foundation work of the building to be done later. After each pipe set was inserted into the drill, its total length was noted.

Even though the insertion of the pipe was very fast after the drill was opened, in some drills the ground collapsed before the pipe was inserted. This resulted in several points where the drill was longer than the pipe inserted (example : the drills was 130 meters but the pipe could only be inserted at 115 meters). The tables and calculations were made for the amount of pipe inserted not length of drill. After the insertion of each pipe the pipe was pressure tested to 6 to 7 bar, to make sure that there is no leakage.


Fig.7-8 Pressure testing

To be in line with the foundation details, 8 drills were placed in line to be connected with a collector. So the available area under the building was split into 15 lines of 8 drills to result in 120 drills.

After several drills were done they were filled by the prepared mixture of cement and sand and water, using a high pressure pump. Other mixtures of bentonite were looked into but could not be found from the local market so were not used. The drills and the pipes were all inserted and then the lines were carried together horizontally with the inlet and outlet pipes separated in batches.

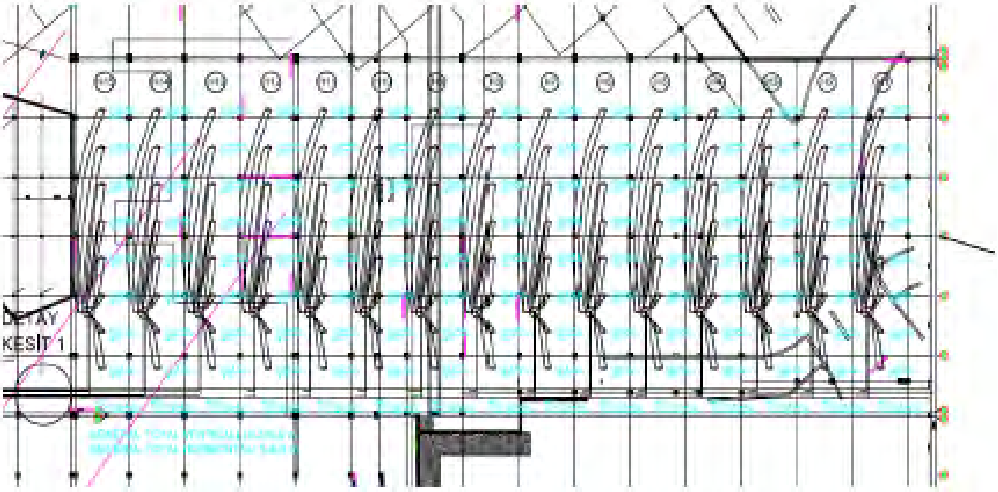


Fig.9 Main Field

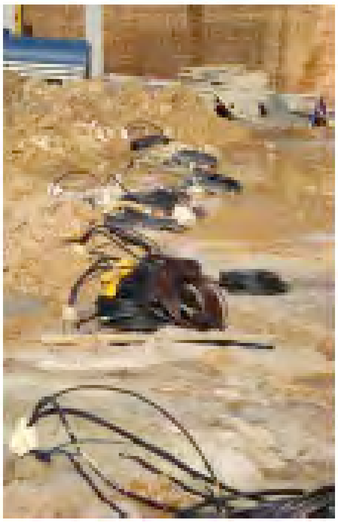


Fig.10 Set of drills Fig.11 General view Fig.12 Grouping of pipes

The finishing of the 120 pipes completely showed that the total length of drilling achieved was 10,333 meters. This was well below the desired level of 120 drills of 150 meters each resulting in 18,000 meters. This was also below the first calculation of 150 drills, due to the lack of space available. To make up for this and to increase the total amount of piping, additional land was investigated and 2 other points outside the building were located and decided. As a result the first part under the building was called Phase 1, the second part next to the building with 8 sets of 8 drills each (total 64 drills) was called Phase 2 and the final part next to the mechanical room with 3 sets of 8 drills (total 24 drills) was called Phase 3 of the project.

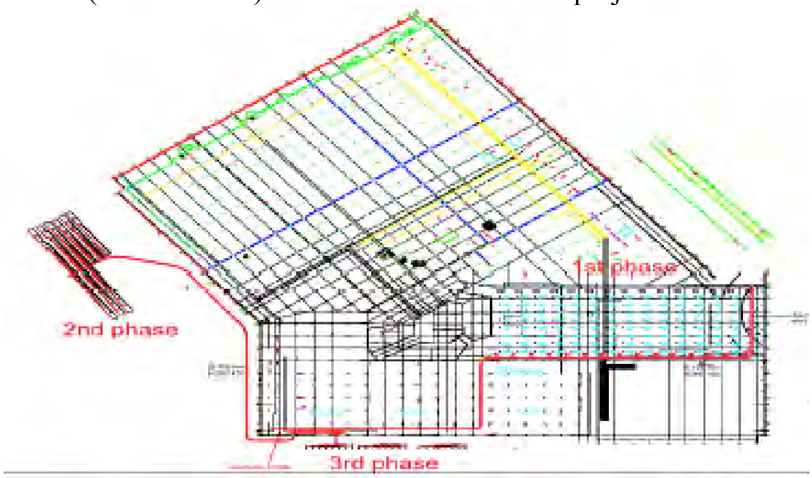


Fig.13. 3 Phases

First all 3 Phases of the drilling were finished and the pipes from each drill were connected to the collectors. Then the collectors were carried with 100 mm size PN16 - SDR11, PE type pipes horizontally to the mechanical room. In the same way as before the collectors, the large horizontal pipes after the collectors were also were carried together horizontally with the inlet and outlet pipes separated in batches up to the mechanical room.

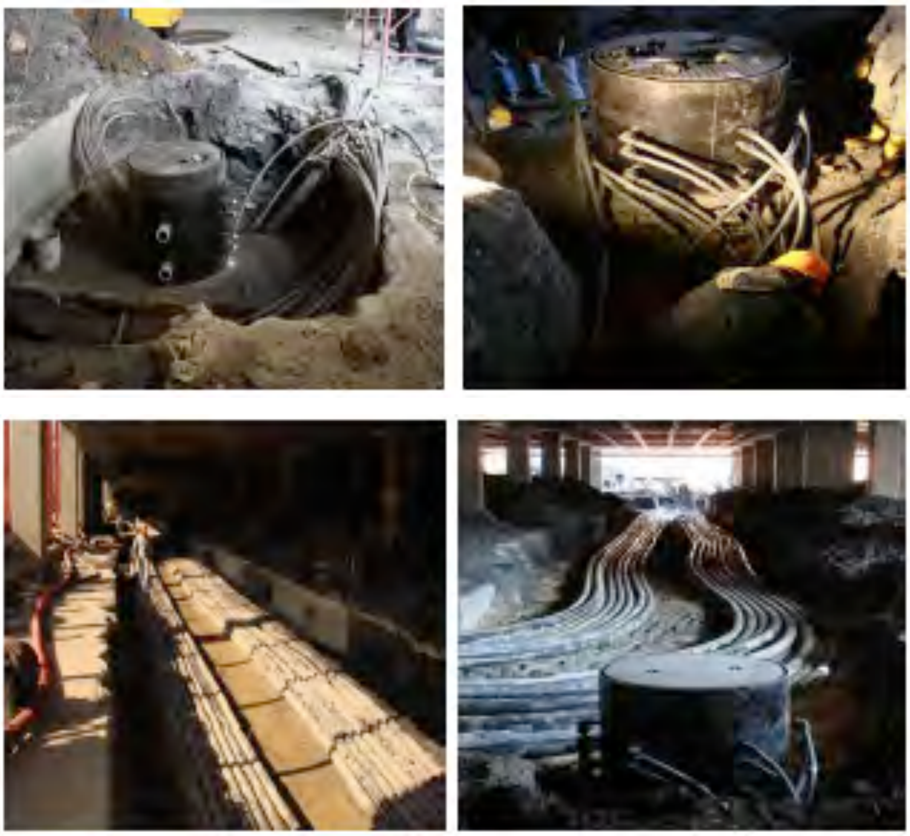


Fig.14-15-16-17 Main piping and collector connections

The pressure testing of the pipes continued at several different levels. After the first insertion, the pipes were also again tested after; the filling of the grouting, the horizontal laying up to the collector, connection to the collector, 8 sets of pipes with the collector and finally after the horizontal piping of the collector to the main collector. This several stages of tests allowed us to make sure that a damage to a pipe is detected before it is connected to the full system and before it is completely covered.

All the drilling, piping, grouting, testing, horizontal carrying was done and the pipes were taken into the mechanical room to be connected to the main collectors there. The 2 main collectors made from metal were 500 mm in size and had 26 pipes of 100 mm PE connected in to them.

Fig.18-19-20 Final mechanical

Piping of 18,327 meters was actually about 36,000 meters of pipes. Including the different lengths of horizontal piping before and after the collectors, the total amount of piping used in the project was about 55,000 meters.

Before the end of the drilling, it also became apparent that due to several changes in the construction and the requirement of the renting companies the size of the loads increased. The new loads were 3,250 kw cooling (% 38 increase) and 1,200 kw heating. As the finished length was 18,327 meters with about a 1,000 kw capacity, the cooling tower had to be selected at 2,500 kw capacity in order to satisfy the full cooling capacity.

No additional boiler was considered as it was thought that the ground would be roughly sufficient for the heating capacity, especially after the summer seasons where it can be loaded with energy. Also the additional heat from the commercial coolers explained below is to help with about 200 kw. In addition to this still as an emergency heat a 400 kw boiler was considered to be put next to the mechanical room.

At the final stages of drilling, a testing of some of the completed ground loops were considered. For this the services of Turkish Cukurova University with Thermal Response test equipment were hired. They tested 5 of the finished boreholes, each for about a 3 day period and made a full report of the study. This showed that on the average, a ground thermal conductivity of 2.6 W/mK is available. This was actually better than the values assumed in the initial calculations done by USA in determining the required length of drilling.

The mechanical design of the building was done with no plate heat exchanger between the ground side and the building side in order to not loose 2c to 3c and have the most efficient system. There were 5 parallel pumps considered for the complete flow, with a frequency controlled system.

For each shop 1 or more units of water to air heat pumps units were chosen. Each of these controlled with a separate thermostat, allowed the zone dedicated to the unit to be cooled or heated at any time during the year depending on the request of the customer. In the larger stores several of these units were used in connection with large size heat pump units up to 190 kw per unit of cooling capacity. The large units were also selected so that they could do free cooling with an air side economizer in case the outdoor condition was suitable for cooling the inside without using mechanical cooling. This was especially the case for the cinemas, where even during winter due to internal loads cooling may be required. All fresh air units were selected as air handling units with wheel type heat recovery to gain the most of out of the exhausted air in terms of energy. In the large retail market area, 2 full fresh air units were also used that worked with Air Quality sensors to make sure the air quality conditions inside are good. All units had solenoids in their water inlet condenser side, to close the water flow in case the compressor was off. This way the water flow could be reduced according to the number of working units by the frequency controlled pumps. There was a minimum set point given to the pumps from the building automation, in order to have sufficient water flow speed from the ground side. The closed circuit cooling tower also was selected with frequency controlled fans in order to have capacity control and the lowest possible sound especially at nights, not to disturb the surrounding living area.



Fig.21 Water to air units Fig.22 Large units Fig.23 Mechanical room

Also the condenser side of the air cooled industrial cooling in the main market (the cold rooms and the freezers) was added with a refrigerant to water condenser that allowed the condenser side to also benefit from the low temperature ground side. This actually also allowed the dumping of the heat to the loop during winter time, acting as a 200 kw capacity boiler for the loop that was missing in calculation. In summer times in order not to over load the ground as the capacity was already short, the normal air cooled condenser was assumed to work.

The flow of the system was designed so that the water returning from the units could be either partially taken thru the cooling tower or non, with a continuously controlled valve. The ground collectors also had a continuous controlled valve to manage the flow of water thru the ground. The set up of the system also allowed the water to be circulated between the ground and the cooling tower, without entering into the units. This was considered necessary in order to charge or cool the ground using the outside air thru the closed circuit tower at nights if necessary.

A very detailed automation was set up so that with close watch, a lot of variables can be observed and in time changes can be made on the control strategy of the system in order to make the complete system operation more efficient.

As a lot of variables had changed since the beginning, including the loads, the total drilling done, etc, a re-evaluation of the system was thought. Using all these new values and re simulating the building in computer software a revised study has been done by USA. This simulation did not incorporate the effects of free cooling to be done using fresh air by the large heat pumps and the heat recovery effect of the fresh air handling units, but it did incorporate the winter ground balancing (cooling) effect of the cooling towers. The additional 2 simulations done, mainly had the below difference in calculation; V3 simulation was using the 1.5 W/m-K ground thermal conductivity and V4 simulation was using the 0.9 W/m-K ground thermal conductivity as a worst case. The main difference between them was that in 20 years the ground temperature increased 2 c more on the worst case V4 simulation.

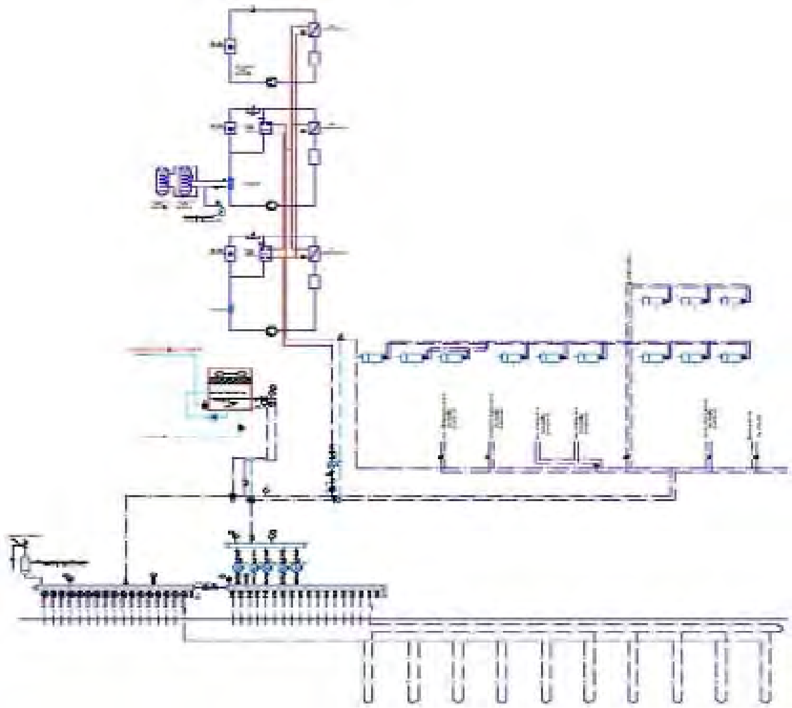


Fig.24 Water piping diagram

The results can be summarized in the below table;

	Year 1 Ground Temp	Year 20 Ground Temp	System COP – Year 1 / 20
Original Simulation	9.1 – 27.0	9.8 – 27.5	——
V3 Simulation	7.6 – 28.5	15.1 – 30.7	3.5 / 3.3
V4 Simulation worst case	6.8 – 28.9	14.6 – 32.7	3.5 / 3.2

During the years, the increase in the low side of the temperature actually increased the efficiency of the heating system, where as the increase in the temperature on the high side decreased the efficiency of the cooling system.

It is obvious that the increase in the load and decrease in the total drill size has made the system less efficient than before in both cooling and heating. Still the loop temperatures are very much in control and do not go into very high or low levels that would not enable the units to operate. The system COP including all the units, pumping and tower energies are calculated to be around 3.5, but this value did not incorporate as mentioned above the effect of free cooling and heat recovery effects. These values can all be improved further, as explained above, if the system is followed regularly and guided in better ways thru the automation system in the correct way.

Fig. 27-28-29 General views

4. RUNNING THE SYSTEM

The first startup of the system was done during August and till now there are still some stores that have not opened fully, but the complex is 95 % in use. The amount of cooling used was very low due to the startup timing and the full utilization of the complex. Due to this the ground has started from a natural stage of about 17 c temperature. This is causing some concern regarding the heating as the temperature in the loop has already dropped down to 12c to 15c levels. If the start had been with a full summer load, the winter would be beginning with a charged ground temperature of 22c to 26c. This would have allowed a much more efficient and trouble free winter usage.

The loop has not been charged with glycol for several reasons. The expected low temperatures are not in freezing point. As the loop is not separated with a plate heat exchanger it is a very big loop consisting of both the underground and inside the building piping, which would have required a very large amount of anti freeze. The loss of efficiency due to anti freeze usage was not desired.

During the second phase of the drills, the pipes were inserted into 7 bore holes together with an OPTIC cable. This cable will allow the measurement of precise temperature in the depths of the used drills. The temperature can be read for each 10 cm and will be collected as data. This will also be one of the first such applications, allowing the ground temperature to be measured in various points along the vertical piping.

The building automation has not been fully operational. So the evaluation of parameters is not yet completely possible. But as indicated before with the large amount of data collection points including usage of condenser energy with each unit, during the coming years a lot of important data can be created using the building automation. It will also be able to guide the control of the system in terms of making it more efficient.

CONCLUSIONS

One of the largest ground source heat pump installations in Europe, in terms of the total drilling size have been completed with 18,327 meters. The estimation of return of investment is around 9 years. Several other energy saving measures have been taken along with it. It is important to follow the actual operation of the building in detail to learn from the experience.

Acknowledgements :

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