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Experiences in the Commercial Application of GSHP Systems in Kosovo

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Abstract: ***One of the most ambitious tasks is raising the share of EU energy consumption produced from renewable resources to 20%. In that direction, due to investments made by EU in rehabilitation of Municipal infrastructure and building of new compounds like Palace of Justice (PoJ) in Prishtina it was required use of geothermal energy source as energy efficient option for heating and cooling combined with heat pumps (Ground Source Heat Pumps; GSHP) . The option to use geothermal energy and type of geothermal system was supposed to be based upon the results of the geotechnical investigation and the investment requirements. All these arguments were basis for the dramatic challenge of GSHP installations in commercial buildings in Kosovo. The realized project of GSHP system in PoJ in Prishtina, funded by EU office in Prishtina, is the biggest in this part of Balkans and the aim of this paper is to present results and experiences from idea till the completion of the project and results achieved during these years of use of this very successful system. The results of geotechnical investigation, TRT (Thermal Response Test), Earth Engineering Design Simulation for thermal modeling of the underground fields of boreholes and technical solutions using BHE as energy sources and comparison between one or several heat pumps centers, will be presented. Some of practical problems and field empirical solutions will be discussed as well.***

Keywords: GSHP, TRT, EED, BHE

1. Objectives

The Design and Build D&B Contractor is required to deliver to the Employer a fully functional, tested and operating buildings and related infrastructure and landscaping as part of the overall Palace of Justice Compound in Kosovo, of approximate area of 49759 m2.

Geothermal energy source is planned to be used as energy efficient option for heating and cooling. Each of the 5 buildings shall have own individual geothermal based HVAC system.

2. Prerequisites

Energy efficient building as prerequisite

The Energy efficient buildings (new constructions or renovated existing buildings) can be defined as buildings that are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipments that will be chosen to heat or cool the building. Therefore, it is considered compulsory design of the building with low heating and cooling demand as per Low energy house.

Heat regime below ground

The surface temperature of the earth, which on average is at around 13 °C throughout the world, is determined by an equilibrium between the radiating solar energy, thermal radiation into space, geothermal heat flow, and variants/interferences of these factors.

The heat transport capacity through conduction at steady state can be described by the thermal conductivity λ (in W/(m · K), and for in-stationary conditions by the thermal diffusivity α (m2/s), The hydraulic conductivity of the rocks in the underground (permeability in m/s) is determinant for the convective heat transport. The specific heat capacity (ρ · cp) is From HVAC design calculations, after reviewing initial calculations, based on reviewer's remarks, there are collected Table 2- The main types of the energy used for heating in city of Korça maximum values for heating and cooling demands as follow determinant for the storage of thermal energy (in kJ/(m3 · K)). All these values have to be taken into consideration during design process.

Site assessment and soil investigations

The respective location is of decisive importance for the design and planning of a plant for the thermal use of the underground. To design of borehole heat exchangers (BHE) for Ground Source Heat Pumps (GSHP) or Underground Thermal Energy Storage (UTES), the knowledge of underground thermal properties is paramount.

In particular for larger plants (like for Palace of Justice compound) the knowledge of underground thermal properties is a prerequisite for correct design of borehole heat exchangers (BHE) and use of Geothermal Energy as main source to cover heating and cooling requirements.

3. Design inputs

The Company as Design and Build Contractor was obliged to fulfil contractual requirements to use geothermal energy and type of geothermal system based upon the argumented local site area geological conditions, duration curve for heating and cooling demand, suitable supposed available area for geothermal boreholes, the results of the geotechnical investigation and the investment requirements.

The design of the BHE field in supposed available area (12.000 m2) should be planned using best European experiences (borehole spacing 6-8m, borehole depth 125-130 m) and explicit confirmation of borehole thermal power. Geological and hydro-geological report for the site both geological and geothermal investigations and interpretation of the test borehole are supposed to be used.

4. Design Solution

Design contains thermal modeling of the underground fields of boreholes using "Thermal simulation EED-software" (earth energy designer). This modeling is based on the TRT test and heating and cooling loads by estimating and system sizing program for buildings.

Table 1: Design calculations of heating and cooling demand per year

	HEATING and COOLING DEMAND CALCULATIONS NEW without consideration of reserves							
	Cooling capacity			Heating capacity				AIR
	Building	Air	ALL	Building	Air	DHW	ALL	
	Qc		∑Qc	Qh			∑Qh	
	W		W	W			W	m3/h
Building A	403360	53500	**456860**	147440	154300	0	**301740**	**32490**
Building B	262320	18800	**281120**	102560	71200	0	**173760**	**14950**
Building C	287680	25000	**312680**	131520	95800	0	**227320**	**20700**
Building D	371520	73000	**444520**	124400	407400	0	**531800**	**89845**
Building E	234400	21000	**255400**	92400	236700	0	**329100**	**49980**
Total	**1559280**	**191300**	**1750580**	**747900**	**965400**	**0**	**1563720**	**207965**

Table 2: Design calculations of monthly distribution of heating and cooling demand

ANNUAL HEATING AND COOLING LOADS

Month	Jan.	Feb.	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Total (kW)
Heating Loads (kWh)	320125	283578	211572	110615	62737	75909	77884	60742	49628	116220	222327	311518	1902855
Cooling Loads(kWh)	25737	33787	66097	108929	172884	319581	354839	339220	188132	105444	38739	23745	1777134
Heating Loads (%)	16.82	14.90	11.12	5.81	3.30	3.99	4.09	3.19	2.61	6.11	11.68	16.37	100.00
Cooling Loads(%)	1.45	1.90	3.72	6.13	9.73	17.98	19.97	19.09	10.59	5.93	2.18	1.34	100.00

From HVAC design calculations, after reviewing initial calculations, based on reviewer's remarks, there are collected maximum values for heating and cooling demands presented in the Table1 and 2, above.

To estimate the annual distribution of the heating and cooling energy demand, climate data of Sofia, Bulgaria were considered as most suitable for our study case. Table 3 shows the assumed distribution for each of buildings in the PoJ compound.

Table 3: Heating and cooling demand for individual buildings in PoJ compound

HEATING AND COOLING DEMANDS FOR BUILDINGS						
Building	A	B	C	D	E	Total
TOTAL Area (m2)	13127	11279	9484	10806	5063	49759
Heating Demand (kW)	339	189	217	602	217	1564
Heating Demand (%)	21.65	12.09	13.88	38.49	13.88	100.00
Specific heating Demand (W/m2)	26	17	23	56	43	31
Annual Heating Demand (kWh/a)	321518	138587	146663	1025201	270886	1902855
Annual Heating Demand (%)	17	7	8	54	14	100.00
Specific Annual heating Demand (kWh/a*m2)	24	12	15	95	54	38
Cooling Demand (kW)	414	274	296	431	240	1655
Cooling Demand (%)	25	17	18	26	15	100
Specific Cooliing Demand (W/m2)	31.54	24.29	31.21	39.89	47.40	33.26
Annual Cooling Demand (kWh/a)	454103	366887	309121	430483	216540	1777135
Annual Cooling Demand (%)	26	21	17	24	12	100
Specific Annual cooling Demand (kWh/a*m2)	35	33	33	40	43	36

BHEF design

Based on request to provide maximum coverage of Heating and cooling demands for all buildings, using available area as BHE field for design available in the compond area,

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designer has provided several simulation results presenting as "optimum" covering 100% heating demands and 80% cooling demands. Field distribution doesn't imply individual centers; more is concentrated to the solution with one center!

Geothermal input parameters

The geothermal input parameters for the EED simulation are presented in table 4 below:

Table 4: Geothermal conditions in Palace of Justice compound

Input parameters	Values
effective thermal conductivity of the subsurface	1,920 W/(m x K).
effective volumetric heat capacity of the subsurface	5.560 MJ/(m³·K)
ground surface temperature	12.34 °C
geothermal heat flux	0.0819 W/m²

Design software and the simulation results

The BHEF is designed by using the software EED 2.0. With this software, the development of heat carrier fluid temperatures is simulated over the time. Thereby, the thermal interactions between the BHEs are considered. To fulfill the temperature constraints defined, the number, depth and location of the BHEs can be changed.

Site plan of the area intended for proper dimensioning of the plot and use of EED must be known. Based on landscape design the free area for drilling of BHE is estimated to be 12000 m2. Taking into accountthe most evaluated designer's proposal, the plot has been entirely covered by 212 boreholes, in a distance of 8 m between their centers, with total length of 26500 m.

Based on geothermal energy source the heating/cooling Center covers: 100 % of the heating demands, 80 % of the cooling demands and 50 % of the domestic hot water demand with heat recovery from heat pumps (First heating stage for DHW).

Table 5: Table of borehole heat exchangers field design

BOREHOLE HEAT EXCHANGERS FIELD DESIGN							
Parameters	Field A1	Field C1	FieldC2	Field D1	Field D2	Field E1	Total
•Number of boreholes	41	18	17	77	47	12	212
• Borehole depth	125						
• Borehole spacing	8						
• Total length (m)	5125	2250	2125	9625	5875	1500	26500
• Annual heating load	427.12	173.08	194.14	738.57	451.934	115.386	2100.23
• Annual cooling load (MWh)	344.351	140.112	132.328	595.46	364.362	93.408	1670.021
• Annual DHW load (MWh)	24.35	10.69	10.096	45.73	27.91	7.127	125.903

5. Discussion of Design solution

In reported design it is clearly shown that available area supposed for drilling of BHE is not sufficient to cover all heating and cooling demands! In fact originally plot was around 26000 m2, and Contractor has failed to use more than enough space on the site to execute geothermal system.

Energy-efficient, climate responsive building requires a whole building perspective that integrates architectural and engineering concerns early in the design process. In our case, the evaluation of a building envelope design has considered its effect on cooling loads and day lighting.

Analyzing window construction with given window details overall shading coefficient or SHGC is taken with some calculations and explanation very high, from 0.26 up to 0.545! This has huge impact on calculations of cooling loads!

Building D and E are inefficient with 95 kWh/m2 annually respectively 54 kWh/m2. They use 68% of required Energy for Heating and 36% for Cooling!

Comparing with the requirements stated in the Table 2. for each building and as total we can conclude that BHEF potential to cover heating loads, excluding DHW of 2100 MWh/a, can cover 1903 MWh/a which means more than 10% of all heating requirements, representing a energy surplus, while potential for cooling purposes as 1670 MWh/a comparing with the requirements 1777 MWh/a means covering of 94% of cooling demands!

The low value of the borehole resistance indicates a good heat transfer between subsurface and heat carrier fluid. Due to high thermal conductivity of the used borehole grouting material a proper filling of the borehole can be assumed. The calculated thermal conductivity of 1.920 W/(m*K) lies within the range given by VDI 4640 for water saturated clayey, sandy, silty sediments with minor parts of gravel. In contrast, the calculated heat capacity of 5.560 MJ/(m³·K) is around twice as high as expected from VDI 4640. An increased heat capacity appears in most TRT tests evaluated with the GeoLogic Software "TRT" as the software calculates an effective heat capacity. According to the software manufacturer this effective heat capacity contains all thermal processes occurring in the subsurface and hence represents the prevailing geothermal situation of the location.

Further optimize system was recommended and possible.

Ventilation demands have to be covered in different way f.ex. direct expansion etc.

In case that cooling cannot be covered 100% with geothermal which source will be used as alternative?! Recommended to find solution with renewable sources, to use absorption as possible option!.

6. Conclusions

During all the phases of construction, starting from early phase of building desig, the possibility of use of geothermal energy as main source for covering of heating and cooling demands for administrative buildings in Kosovo has been considered and energy savings results has shown an excellent example in RES use for such buildings. Authors has collected following conclusions:

- Use of geothermal energy source and other efficient energy sources as well requires very carefully design of the buildings as consumers!. They have to fulfill requirements for Energy efficient Building according to German EnEV, GermanWSVO 95 and/or other European Norms European standard EN 12831/ VDI 2078

- The geological soil investigations and knowledge of the underground characteristics is very important to design an installation using Borehole Thermal Energy Storage (BTES)
- The ground thermal properties and the heat-transfer efficiency of the borehole heat exchanger (BHE) system using TRT are key parameters and mandatory for designing ground-coupled systems. Proper design of such systems requires good knowledge of these parameters, providing an efficient and economic operation.
- In very large and complex tasks EED is highly recommended because allows for retrieving the approximate required size and layout before initiating more detailed analyses. Even for very small plants EED values the effort to do a calculation instead of using rules of thumb is worthwhile.

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