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REHVA Guidebook No 20
Advanced system design and operation of GEOTABS buildings

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List of content

1. Terminology, Symbols and Units
2. Introduction
3. What is GEOTABS?
4. Possibilities and Limitations of GEOTABS
5. GEOTABS: Designing the Ground System
6. GEOTABS: Designing the Building
7. GEOTABS: System Integration
8. GEOTABS: Commissioning, Operation & Maintenance
9. Outlook
10. GEOTABS Buildings – Diversity of Solutions
References
Terminology

**Geothermal energy**
Energy stored below the surface of the solid earth in the form of thermal energy.

**Heat pump**
Heat pumps are thermodynamic cycles by means of which low temperature ambient energy can be upgraded such that it can be utilized for heating (heat pump) or cooling (chiller) buildings. The ambient energy is extracted from the ambient air, the groundwater or the ground soil. By using electrical power the temperature is brought to the desired temperature.

**Thermally Activated Building System (TABS)**
Radiant heating and cooling systems with pipes embedded in the building structure (slabs, walls).
What is GEOTABS?

GEOTABS is an acronym for a geo
ermal heat pump combined with a
thermally activated building system, used for conditioning of a building in
three possible modes:

- Heating with a heat pump
- Passive cooling
- Active cooling with a reversible heat pump
The TABS is a building component with embedded water based pipes used for heating and cooling the building.

The principle of the system is to activate the thermal mass of the building to transfer heat to or from the zone to assure thermal comfort in the rooms.
TABS

The system can be effectively used in combination with renewable energy sources and heat pump for:

- low temperature heating (27 - 29°C)
- high temperature cooling (18 - 22°C)
TABS

- Drift of the indoor temperature in a TABS building (example: summer)

- TABS should be used for zone control - not for individual room control!
Heat pump

Principle of the heat pump:

Types of heat pumps:
- in regard to heat source: air, water or ground coupled heat pumps
- in regard to supply energy source: electrical, gas or oil combustion
- in regard to conversions: compressor, absorption or adsorption
Near surface geothermal energy systems

Closed systems
- Horizontal heat exchanger
- Borehole heat exchanger
- Energy piles
- Slabs as ground absorber

Open systems
- Wells
Seasonal thermal balance in the ground

Underground Thermal Energy Storage (UTES)
- combined heat source and heat sink
Seasonal thermal balance in the ground

Only heat source

Only heat sink

Regeneration of the natural thermal balance of the soil must be assured!
## Possibilities and limitations of GEOTABS

<table>
<thead>
<tr>
<th>Strength</th>
<th>Weakness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water supply temperatures:</td>
<td>1. Limited average thermal power output of 40 to 50 W/m². Allow temperature drifts within the specified comfort range or provide an additional, fast reacting system.</td>
</tr>
<tr>
<td>- &lt;30°C for heating</td>
<td>2. Limited individual room control.</td>
</tr>
<tr>
<td>- &gt;15°C for cooling</td>
<td>3. Not useful to change set-point during a day.</td>
</tr>
<tr>
<td>exploiting environmental energy: (ground coupled) heat pumps, passive cooling and night cooling.</td>
<td>4. Acoustic control - limited suspended ceiling.</td>
</tr>
<tr>
<td>2. Large thermal capacity (time constants of 10-15h) to shift TABS operation to time periods when heat and cold production is most energy (or cost) efficient.</td>
<td></td>
</tr>
<tr>
<td>3. Increased thermal comfort by radiation heat exchange.</td>
<td></td>
</tr>
<tr>
<td>4. Reduced building height compared to buildings with full AC.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Suitable for low energy, passive or zero-energy buildings.</td>
<td>1. Careful system and control strategies design is required.</td>
</tr>
<tr>
<td>2. Increased share of efficiently generated heat and cold.</td>
<td>2. Additional fast reacting system must not overrule or counteract the TABS operation.</td>
</tr>
<tr>
<td>3. Less expensive and more energy efficient form of cooling than full air-conditioning.</td>
<td>3. The limits of the system regarding the achievable thermal power should be specified.</td>
</tr>
</tbody>
</table>
Design process

**feasibility study** (estimation of feasibility):
- building type, concept and location
- specification of requirements
- heating and cooling demand
- availability and properties of the ground
- local regulations
- financial constraints

**method:** estimation, rule of thumbs

**pre-design** (rough sizing):
- building design and performance (base and peak loads)
- thermal balance (internal and external heat gains and losses)
- thermal storage mass of the building
- type of ground heat exchanger
- GEOTABS concept
- additional and back-up system (if required)

**method:** calculations, norms and standards

**detailed design** (detailed sizing):
- zoning and rooms characteristics
- TABS design
- heat pump and geothermal system design
- hydraulic system design
- integration of the systems
- control strategy

**method:** dynamic simulations, performance simulations
Designing the ground system

Realization of a geothermal system requires adaptation to the geological constraints on site:

- rock type and hardness
- ground thermal characteristic
- groundwater situation
- natural ground temperature

A thermal response test (TRT) and exploration of the soil can provide information on the suitability for geothermal systems.
Simulation of the ground system

Simulation is particularly useful to study:

- the thermal response of different borehole configurations
- interference between boreholes
- annual energy balance of the ground

Types of simulations:

- coupled simulations (TRNSYS, eQuest, EnergyPlus, Modelica)
- decoupled simulations (Earth Energy Designer – EED, EWS – Erdwärmesonden)
Designing the building

The main restrictions for the design are related to:

• mass of the building
• external gains and losses related mostly to location, orientation, layout (internal, external and corner rooms), ventilation and solar radiation
• internal loads
• transmission
Simulation of the building

Simulation in design of the GEOTABS building on:

- building level
- room level
- TABS level

Example of the temperature profile output of building simulation with TABS
System integration

Heat pump in combination with the additional heating or cooling system – operation modes:

- monovalent
- bivalent – alternative
- bivalent – parallel
- bivalent – partially parallel
- monoenergetic

Heating with integrated district heating
System integration

Passive cooling

Active cooling

Cooling with integrated cooling tower
System integration – buffer tank

Buffer tank to avoid frequent on/off switching of the heat pump, when:

- the supply system contains only a small amount of water
- it is running at very low loads
- the supply system can be turned off completely
Efficiency of the system

- **Coefficient of Performance (COP)**
  the ratio of heat power to electric power referred to particular boundary conditions (calculated value)

- **Seasonal Performance Factor (SPF)**
  the ratio of annual thermal energy output to the annual consumed electrical energy (measured value)
Control strategies for the ground system

Conventional control strategies:
Intermittent operation with defined schedules:
• with a dead band for a specific range of temperatures or with seasonal downtime
• only during occupation hours (night setback)
• independent from occupancy time, when the energy tariffs are lower (night cooling)

Rules for ground system control:
• avoid frequent switching between operation modes
• decrease unnecessary consumption of auxiliary energy
Control strategies for TABS

Conventional control strategies:

- Time based control
- Zone temperature control
- Weather dependent supply/average water temperature control
- Intermittent pump operation control
- Constant concrete core temperature control
- Dead band for switching between heating and cooling mode
Control strategies for TABS

Rules for TABS control:

- keep TABS at a constant temperature
- concrete surface temperature is the controlled variable, water temperature is the manipulated variable
- heating on, if average outdoor temperature is lower than set point
- cooling on, if average outdoor temperature rises above the set point
- heating/cooling curve +3K / -3K
Control strategies for additional systems

Conventional control strategies:
• operation of the TABS system during night and use fast reacting system during daytime
• operation of fast reacting systems at moderate ambient air temperatures
• activation of the TABS when the building is constantly in heating or cooling mode

Rules for fast reacting system control:
• fast reacting systems must not overrule the TABS in regular operation
• simultaneous heating and cooling must be avoided
• frequent changing between heating and cooling must be avoided
Control strategies – Model Predictive Control

Model Predictive Control (MPC) framework:
Commissioning, operation & maintenance

Commissioning is an essential requirement for GEOTABS systems in commercial buildings to ensure that the system operates in the intended way!

Commissioning process
Step 1: Definition of objectives
Step 2: Definition of measurement and verification concept
Step 3: Initial Commissioning
Step 4: On-going Commissioning
Real cases

Hollandsch Huys

<table>
<thead>
<tr>
<th>Location</th>
<th>Hasselt, Belgium</th>
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</thead>
<tbody>
<tr>
<td>Year of construction</td>
<td>2008</td>
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<tr>
<td>Net floor area (NFA)</td>
<td>4 090 m²</td>
</tr>
<tr>
<td>Gross volume</td>
<td>12 975 m³</td>
</tr>
<tr>
<td>Geothermal system</td>
<td>Borehole Heat Exchanger (22 à 75 m)</td>
</tr>
</tbody>
</table>

**Design values**

- Total heating load: 37 kWh/m²
- Total cooling load: 27 kWh/m²
- Fraction of geothermal system: Heating: 100%    Cooling: 100%

Summer and winter energy concept
Real cases

INFRAX West

<table>
<thead>
<tr>
<th>Location</th>
<th>Torhout, Belgium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of construction</td>
<td>2009</td>
</tr>
<tr>
<td>Net floor area (NFA)</td>
<td>4 014 m²</td>
</tr>
<tr>
<td>Gross volume</td>
<td>21 484 m³</td>
</tr>
<tr>
<td>Geothermal system</td>
<td>Borehole Heat Exchanger (24 à 130 m)</td>
</tr>
</tbody>
</table>

**Design values**

| Total heating load | 409 kW | 71 kWh/m²_{NFA} |
| Total cooling load | 242 kW | 49 kWh/m²_{NFA} |
| Fraction of geothermal system | Heating: 69% | Cooling: 67% |

Summer and winter energy concept
More GEOTABS cases with building characteristic and operation data at:

www.geotabs.synavision.de
Thank you for your attention

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