Passivhaus Breakfast Seminar
Building Centre 14th November 2012

8.00 – 8.30 Registration and breakfast
8.30 – 8.40 Welcome and introduction Mike Moseley
8.40 – 9.10 Introduction to Passivhaus standards. Jon Bootland UK Passivhaus Trust
9.10 – 9.40 REHAU composite GENEIO Passivhaus window system Tony O'Neill
9.40 – 10.10 Window project examples and case studies Bob Jenkins, Solar Windows
10.10 – 10.40 Introduction to REHAU 's Ground Air Heat Exchanger Mike Moseley
10.40 – 11.00 Panel 'Question and Answer' session
GROUND-AIR HEAT EXCHANGER CPD
RENEWABLE SOURCE OF VENTILATION

www.rehau.co.uk
LEARNING OBJECTIVES

• Introduction to REHAU
• How a Ground-air Heat Exchanger (GAHE) works
• Requirements for GAHE pipe material
• Design / installation criteria
• Design software for GAHE
• Case studies
REHAU COMPANY HISTORY

UK LOCATIONS

Private Company

- 1948  Founded in the Bavarian town of REHAU
- 1962  First UK Sales Office and Warehouse
        opened in Slough
- 1975  First Manufacturing Plant was opened in
        Amlwch
- 1995  Opening of the new headquarters in
        Ross-on-Wye
- 2012  REHAU celebrated its 50th anniversary
        trading in the UK
REHAU WORLDWIDE
THINK GLOBALLY – ACT LOCALLY

6 CONTINENTS
174 LOCATIONS
OVER 15,000 EMPLOYEES

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REHAU DIVISIONS
UNLIMITED POLYMER SOLUTIONS

Industry
FURNITURE, HOUSEHOLD APPLIANCES, HOSES AND INDUSTRIAL DEVELOPEMENTS

Automotive
EXTERIOR, WATER MANAGEMENT, AIR MANAGEMENT & SEALING

Building Solutions
WINDOW AND CURTAIN WALLING TECHNOLOGY, BUILDING TECHNOLOGY, CIVIL ENGINEERING
INTRODUCTION
WHAT TYPES OF GEOTHERMAL ENERGY ARE THERE?

Deep geothermal (from within the ground) (> 400m)
- **Hydrothermal systems** *(using water stores)*
- **Petrothermal systems** *(artificially pumping water deep underground)*
- **Deep geothermal probes** *(using a closed loop system)*

Ground-source (from the sun) (< 400m)
- **Ground-source collectors** *(sub-surface, at a depth of 1.5m)*
- **Ground-source probes** *(using boreholes at depths of ca. 100m)*
- **Ground-source spiral probes** *(spiral probes up to 5m deep)*
- **Ground-source energy piles** *(using the building foundations)*
- **Ground water bore holes** *(open loop systems using groundwater)*
- **Ground-air heat exchanger** *(using mechanical ventilation)*
INTRODUCTION
SEASONAL VARIATIONS OF GROUND TEMPERATURE

Temperature °C

Depth (m)

February
May
August
November

AWADUKT Thermo installation depth

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INTRODUCTION
THE ADVANTAGES OF GROUND-SOURCE ENERGY

- Renewable and sustainable energy source
- Year round usage – independent from climate & season
- Reduced carbon emissions for both heating and cooling
- Future-proof source
- Low maintenance costs
- Hidden from view
INTRODUCTION
HOW A GROUND-AIR HEAT EXCHANGER WORKS

Summer operation of a GAHE

Winter operation of a GAHE
INTRODUCTION

EFFECT ON TEMPERATURE PROFILE

‘Contraction’ of the annual temperature profile

Example:

Winter: Pre-warming of 9 K
Summer: Pre-cooling of 14 K

-5° C (Winter)

30 °C (Summer)

16° C

4° C

“contracted” temperature profile

Pre-warming of e.g. 9 K

Pre-cooling of e.g. 14 K

Saving of cooling energy

Saving of heating energy

© REHAU
INTRODUCTION

MEASURED COOLING EFFECT OF A GROUND-AIR HEAT EXCHANGER

Animation of a diurnal variation of the temperatures in the heat exchanger pipe and in the surrounding soil at the head office REHAU, Erlangen (Germany)
EXAMPLE OF A DOMESTIC APPLICATION
COMBINATION WITH HEAT RECOVERY UNIT

1. Suction of fresh air
2. Pre-warming of fresh air by ground
3. Mechanical ventilation with heat recovery (MVHR)
4. Distribution of fresh air
5. Warm internal air extracted from the rooms
6. Expel the extracted air from the building (after heat recovery)
**INTRODUCTION**

**WHY USE MECHANICAL VENTILATION?**

Mechanical ventilation is required when there is not enough air exchange between the air inside the building and the outside air.

For low-energy and passive houses, mechanical ventilation is considered essential due to excellent insulation standards and air tightness.

Ground-air heat exchangers are regarded as a Passivhaus principle.

*Source: Passivhaus UK / BRE*
INTRODUCTION
MECHANICAL VENTILATION WITH HEAT RECOVERY

Expelled warm, stale air from inside the building passes alongside the external pre-warmed air drawn into the building (via the ground-air heat exchanger). MVHR units typically operate at around 90% efficiency.

GAHE connects onto the fresh air inlet

(from bathrooms and kitchens)
Disadvantages of passive ventilation

- Poor air quality (e.g. odours, air humidity too high/low)
- High CO₂ concentration
- Noise pollution
- Window ventilation can be hazardous (security / height risk)

Advantages of mechanical ventilation with GAHE:

- Constant filtered, fresh air supply
- Savings of up to 20% of heating energy and 80% of cooling energy
- Ventilation in noisy areas possible
- No mould growth and inhibited dust mite growth
Potential disadvantages of air conditioning:

- Draughts
- High air speeds
- Cold air temperatures
- Noise
- Contributes to ‘Sick Building Syndrome’
- Expensive running & maintenance costs
- Reduced moisture content in the air
# BREEAM VENTILATION REQUIREMENTS
**Using Example of a School**

## Health & Well-being Section

| HW11 | Where EITHER  
|------|--------------  
|      | In the case of mechanically ventilated and air conditioned buildings:  
|      | • Fresh air is provided at a rate of 8 litres per second per person at normal occupancy and 3 litres per second per person at maximum occupancy.  
|      | OR  
|      | In the case of naturally ventilated buildings the following are all achieved:  
|      | • Trickle vents are provided at the rate of 400mm² per m² of floor area  
|      | • The credit for occupant controlled natural ventilation (HW06) is achieved.  
|      | • The plan depth of the building is less than 15m. Where the plan depth of the building exceeds 15m additional ventilation measures (such as passive stack ventilation or a central atrium) must also be provided.  
|      | 0.83 |

## Energy section

| E20 | Where evidence can be provided to demonstrate that the design incorporates a system of providing free cooling to completely displace the need for a mechanical cooling system (excluding exceptional circumstances, for example server rooms) and the thermal comfort requirements of credit HW14 are achieved. Compliance with this credit will be shown if the design has used a free cooling technology, such as:  
|-----|--------------------------------------------------  
|     | • Night-time cooling requires fabric to have a high thermal mass,  
|     | • Ground coupled air cooling  
|     | • Displacement ventilation,  
|     | • Ground water cooling,  
|     | • Surface water cooling,  
|     | • Evaporative cooling, direct or indirect,  
|     | • Desiccant dehumidification and evaporative cooling, using waste heat,  
|     | • Absorption cooling, using waste heat.  
|     | 1.00 |
When measured at seated head height, the average concentration of CO2 dioxide should be < 1500 parts per million (ppm).

a) All occupied areas shall have controllable ventilation at a minimum rate of 3 l/s per person

b) All teaching accommodation shall also be capable of being ventilated at a minimum rate of 8 l/s per person

2007 University of Reading study on primary schools found that a well ventilated classroom improved pupils’ performance by ca. 5-7%. Pupils also showed less tiredness, increased alertness and attention.
PIPE REQUIREMENTS
FOR OPTIMUM G.A.H.E PERFORMANCE

- No condensation accumulation
- No microbial growth
- Good heat conductivity
- Radon-proof system
- Rigid pipe to prevent tree root growth
CONDENSATION DISCHARGE
WHY CONDENSATION BUILDS UP

Cooling of air from approx. 25°C to 16°C produces significant amounts of condensation in the pipe system, especially in the summer.

This must be removed to:

- Ensure continuing performance of the G.A.H.E
- To avoid microbial growth
- Avoid potential musty smells
ANTI-MICROBIAL INNER LAYER
THE HISTORY OF SILVER AS AN ANTI-MICROBIAL AGENT

• **Egypt 4000 BC.**:
  Silver vessels are used to treat drinking water in ancient Egypt.

• **11th Century**:
  Chalices are made from silver for hygiene reasons.

• **20th Century**:
  There are annually just in the USA alone over 3 million formulas for drugs containing silver

• **2002**
  Bosch and Siemens introduce the first anti-microbial fridges

• **2003**
  REHAU develops the first G.A.H.E pipe
An antimicrobial effect is achievable via integration of silver particles into the pipe inner layer.

An experiment by the Institut Fresenius (Jan 2003) confirmed a significant reduction in microbe growth using this method:
ANTI-MICROBIAL INNER LAYER
RESULTS OF INDEPENDENT TESTING

Silver lining also prevents growth of Legionella pneumophila

Source: Ergebnis Institut Fresenius Jan 2003
THERMAL CONDUCTIVITY
POLYPROPYLENE’S HEAT TRANSFER ABILITY

- Polypropylene has a higher heat conductivity than PVC

- Optimal heat transfer from ground through the pipe into the air

- For core-foamed PVC pipes and outside corrugated connecting pipes, there is a high insulating effect.
POLYPROPYLENE PIPE SYSTEM

The jointing system must also be radon-proof. The required impermeability can be achieved with the safety joint.

- Permanently secure sealing ring
- No pushing/pulling out of sealing ring possible
- Pressure tested to BS EN 1610
- Can withstand jetting pressure of 100 Bar / 1450 PSI
- Pipe joint can withstand 0.5 bar
Radon is a naturally-occurring radioactive gas.

- Found in stones and the ground, comes from the radioactive decay of uranium and thorium

- Diffused into the ground, dissolved in water and escapes out the earth’s upper surface into the atmosphere.
AIR INLET TOWER
INLET TOWER MADE OF STAINLESS STEEL

Pre-filtering of the supply air is done using a G4 filter according to DIN EN 779.

- Improves the air quality by filtering dust & pollen
- Minimises contamination of G.A.H.E pipe system
- Corrosion resistant stainless steel
Domestic:

- Air flow rate between 150 - 450 m³/h
- Pipe size DN200/250 sufficient
- Usually pipes laid as a ring in an existing trench
- At least 40m total length
SYSTEM DESIGN
PIPE LAYOUT - COMMERCIAL

Commercial:

- Air flow rate < 24,000m³/h
- Pipes laid in a ‘Tichelmann’ layout (self-balancing)
- DN 200–250 pipes for heat transfer
- DN 500-1200 pipes for the header pipe
SYSTEM DESIGN
KEY CONSIDERATIONS

- Laying depth approx. 1.5 m to 2 m
- Fall of ca. 2 % to the condensation discharge
- Backfill material shall be compactable
- Distance between pipes is at least 1m (pipe centres)
- Air velocity between 1-3 m/s
- Pressure losses must be considered (<50Pa optimal)
SYSTEM DESIGN
AIR FLOW RATE PARAMETERS

- Aim: to avoid noise!
- Max. air velocity in header pipes < 6 m/s
- Max. air velocity in heat transfer pipes < 3 m/s
- If there is enough space, DN200/250 should always be used for heat transfer

<table>
<thead>
<tr>
<th>Header pipe</th>
<th>Maximum air flow rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN 200 / ID 186</td>
<td>650 m³/h</td>
</tr>
<tr>
<td>DN 250 / ID 232</td>
<td>1,000 m³/h</td>
</tr>
<tr>
<td>DN 315 / ID 293</td>
<td>1,500 m³/h</td>
</tr>
<tr>
<td>DN 400 / ID 373</td>
<td>2,500 m³/h</td>
</tr>
<tr>
<td>DN 500 / ID 466</td>
<td>3,500 m³/h</td>
</tr>
<tr>
<td>DN 630 / ID 582</td>
<td>5,700 m³/h</td>
</tr>
<tr>
<td>DN 800 / ID 750</td>
<td>9,500 m³/h</td>
</tr>
<tr>
<td>DN 962 / ID 900</td>
<td>13,800 m³/h</td>
</tr>
<tr>
<td>DN 1128 / ID 1050</td>
<td>18,500 m³/h</td>
</tr>
<tr>
<td>DN 1300 / ID 1200</td>
<td>24,000 m³/h</td>
</tr>
</tbody>
</table>
VDI Guidelines 4640: Thermal Use of Underground: Part 4

Covers:
- Definitions of G.A.H.E
- System design
- Performance factors
- Maintenance of systems
- Pipe materials

Dual Language – German/English
Cleaning of a GAHE is recommended at least every year to ensure optimal performance.

Possible cleaning options:

- High-pressure water jetting
- Rotarised brush
- Fogging (according to HVCA TR/19 guidelines)

Rotarised brushes (better for single pipe runs)

Water jetting (better for large grid systems)
SYSTEM DESIGN

VARIABLE FACTORS

Output of G.A.H.E is dependent on:

- Weather region
- Thermal properties of the ground
- Water content of the ground
- Air flow rate
- Pipe length
- Pipe material
- Installation depth
- Distance between pipes
REHAU have bespoke design software to calculate the estimated energy savings:

Requirements for calculation:

- Air flow rate
- Location / weather region
- Space available for grid
- Operating hours and days
- Soil type
Weather data:

- UK and European data available
- Source: IWEC
Operating hours:

• Extremely flexible, can choose different ventilation schemes for different days, e.g. just weekdays

• Can vary operating hours for each scheme
Software outputs:

- Energy savings for heating & cooling (kWh/a)
- Max & min. temperatures coming out of GAHE
- No. of operating hours for heating and cooling modes
- Pressure losses
- Air velocities through header pipes and heat transfer pipes
Graphical software outputs show both effect of GAHE on temperatures and energy gain by month (blue for cooling, red for heating).
SYSTEM DESIGN
OPTIONAL BYPASS SYSTEM

- Used to bypass G.A.H.E network on ‘unfavourable’ days
- Consists of additional air inlet tower at end of system
- Dampers need to be controlled based on real-time temperature measurements
- Increases total energy savings from the system (eliminates negative effect)
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

REHAU Head Office - Erlangen, Germany

- Flow rate: 13,000 m³/h
- Annual CO2 savings: ca. 9,200 kg
- Heat transfer pipe DN250
- Header pipe DN800
- 30 runs x 50m long

Almost 120 sensors for temperature, humidity, flow rate, differential and pressure

Installation of a meteorological station to log weather data
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

Diurnal variation of measured inlet & outlet temperatures – summer mode

Summer operation: Cooling of air from 33 °C to 20 °C by the GAHE on 23.08.2011
Diurnal variation of measured inlet & outlet temperatures – winter mode

Winter operation: Heating of air from -18 °C to -1 °C by the GAHE on 06.02.2012
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

TESCO stores in Poland (10 installed so far)

Typical project sizes:
- Supermarket size ca. 1,000 m² to 2,000 m²
- Air flow rate 2,000-6,000 m³/h
- Space Heating demand 50-90 kW
- Space Cooling demand 30-70 kW
- All using MVHR

Outcome of measured projects:
- Reduction of energy demand by 30% (mainly cooling)
- Reduced investment costs due to smaller HVAC plant
- Ave. payback calculated by Tesco ca. 8.5 years
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

Tesco Supermarket, Kingsbridge, Devon

- Recovering heat from chillers, using it for pre-heating. All pipes were under the building.
- 3 runs of ca. 40m of DN500 pipes
- 1 central condensation chamber DN1200
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

QE School, Wimborne, Dorset

- Flow rate: 36,000 m³/h
- 3 Tichelmann grids, each 60m long
- DN1200 header pipe
- 60 AWADUKT Thermo runs of DN250, total length of 3,500m
- BSF ‘Pathfinder’ school

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**CASE STUDIES**

**GROUND-AIR HEAT EXCHANGER**

**Banff & Buchan College, Fraserburgh, Scotland**

- Flow rate: 16,000 m$^3$/h
- DN 1050 header pipes
- 30 x 42m runs of DN250 AWADUKT Thermo

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CASE STUDIES
GROUND-AIR HEAT EXCHANGER

Carclaze School, Cornwall

- Flow rate: 3,457 m$^3$/h
- DN500 AWA Thermo header pipes
- 16 x 30m runs of DN200 AWADUKT Thermo
Tuke School, London

- Flow rate: 9,000 m$^3$/h
- DN1050 header pipes
- 5 x 30m runs of DN 500 AWADUKT Thermo
- Special methane resistant NBR seals
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

South Lanarkshire House

- Showcase example of Code 5 Social Housing project
- 40m of DN200 Awadukt Thermo
CASE STUDIES
GROUND-AIR HEAT EXCHANGER

Interserve Offices, Leicester

- Flow rate: 2,160 m³/h
- DN 400 header pipes
- 21m x DN 200 AWADUKT Thermo runs

1 of only 3 UK ‘PassivHaus’ certified office buildings
RENEWABLE ENERGY SOLUTIONS
RELIABILITY FOR GENERATIONS

Ground-air heat exchanger
Low energy windows / curtain walling
District heating pipework
Underfloor heating/cooling
Ground-source probes/collectors
Stormwater management
Rainwater harvesting
THANK YOU FOR YOUR ATTENTION
ANY QUESTIONS?