Energy storage concrete

Thermal Activated Buildings

Information sheet Simulation

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Interreg
Alpine Space
Co-funded by the European Union
Cool*Alps

Climate-neutral by 2040

„We need to use all our available resources to achieve climate neutrality in Austria by 2040. Hereby thermally activated building structures represent an important step in the right direction. Because emissions must be reduced to zero also in the building sector. Innovative technologies like this support this goal considerably.“

Minister for Climate Action Leonore Gewessler

Fig. 1 top left © **Centre for Solar Energy and Hydrogen Research** Baden-Württemberg

Fig. 2 Wind Lower Austria @ stock.adobe.com

Fig. 3 right **project Sommerein** @Christian Husar

Thermal activated building systems (TABs) support the use of renewable energy for heating and cooling thanks to its storage efficiency

In order to achieve the climate protection targets, the building stock must become CO2 neutral by 2040. This includes both - reducing overall energy consumption and replacing fossil fuels with renewable energy sources.

Climate scenarios indicate a significant increase in heat waves and extreme weather events. In particular in the Alpine region, there will be a steady increase in hot days, which will lead to a significant increase in building cooling energy requirements.

Utilising the capacity of existing building components to store heat is an essential contribution to the development of a renewable energy system, as this can make a significant contribution to balancing out the uneven distribution of energy production and consumption that is typical of renewable energies.

With the ‘Cool*Alps - TABS goes Green Deal’ project, the Interreg Alpine Space programme is supporting the application of the thermal storage capacity of building components to maximise the use of renewable energy for heating and cooling buildings with the aim of improving adaptability to climate change and energy security in the Alpine region.

This information sheet summarises basic findings from the project on the topic of thermal activated building systems in renovation.

What contribution can the construction industry make to achieving the climate targets?

Bmstr. Ing. Robert Jägersberger
Federal Guild Master in Building, @ Wilke – Das Fotostudio

The development towards sustainable buildings undoubtedly places new demands on the construction industry. TABs are a promising solution that offers both ecological and economic benefits. Its versatility in terms of heating and cooling makes it particularly attractive, especially in view of the increasing need for cooling during hot periods.

The fact that TABs work with existing building elements also makes it financially attractive and facilitates integration into existing structures. The savings in operating costs and the possibility of integrating renewable energy systems make it an interesting option.

Solid buildings have a certain storage capacity regardless of the quality of the building and the type of heat emission system. The better the insulation standard, the longer the stored heat can maintain the room temperature in the comfort range. Studies have shown that - depending on the insulation standard of the building - a period of up to 5 days can be bridged without an energy supply. The technology can therefore be easily combined with renewable energy systems.

However, thorough planning is essential to ensure the full efficiency and functionality of this system. This information sheet is intended to supplement the planning guide 'Energy Storage Concrete - Thermal Building Element Activation' published by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology in 2016 by highlighting current developments and possibilities.

Overall, thermal thermal activated building systems is a promising technology that not only fulfils the current requirements for sustainable construction but can also make a significant contribution to achieving climate targets. It is encouraging to see how innovations in the construction industry can help to shape a more sustainable future.

Thermal activated building systems - what does that mean?

Thermal activated building systems (TABs) are a simple technology. They have been a standard system for heating and cooling in the commercial sector for many years and are also gaining ground in residential buildings. With climate change and the energy transition, the utilisation of the storage capacity of solid building components is becoming increasingly interesting.

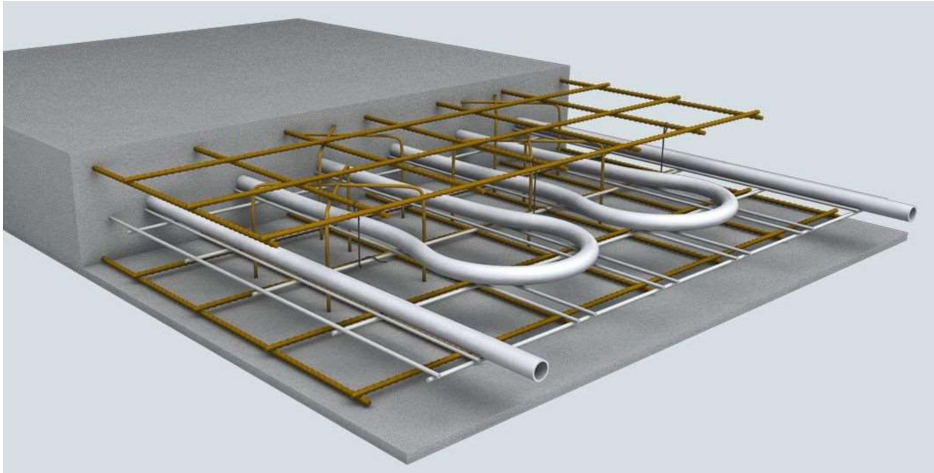


Fig. 4 **Model of an activated concrete ceiling** - the pipe system is mounted in the centre of the component (@ Uponor)

TAB is a surface heating and/or cooling system in which pipes are integrated into solid building components through which water flows as a heating or cooling medium. The component is thermally activated and releases heat over its entire surface or absorbs it again - depending on the heating or cooling mode.
In contrast to underfloor heating, which is laid in the screed, with TAB the pipes are laid close to the surface or in the core of concrete ceilings or walls before the concrete is poured.

A good thermal building standard is a prerequisite if the TAB is the only heating system, and the activated components are to be sufficient and no other heat dissipation systems such as radiators or underfloor heating are required.
From a structural point of view, no changes are necessary, as the usual concrete slab thicknesses are sufficient to integrate the pipe system.

The system temperatures can be kept very low due to the large transfer surfaces. The temperature difference between the surface and the room air is approx. 1°- 6°C. Building thermal activated building systems is therefore very well suited to the utilisation of renewable energies.

In addition to the release of heat for heating, the activation of ceilings is ideal for room temperature control in the warmer months of the year. Cooling via the activated components is perceived as particularly pleasant, scores highly in terms of energy efficiency and ensures optimum comfort for the occupants.

You can find more information on the prerequisites and general requirements in the planning guide Energy Storage Concrete: Thermal thermal activated building systems: **nachhaltigwirtschaften.at** <<

Fig. 5 **Refurbishment project** in Vienna @ Florian Frey

Fig. 6 **Multifamily house 'Tante Käthes Grätz'l'** ©Baumschlager Hutter Partners / Lukas Drobney

The advantages of the system summarised:

- Heating and cooling with one system
- Energy flexibility through storage efficiency
- Low investment and operating costs
- Can be easily combined with renewable energy
- Low, energetically favorable flow temperature level
- Low surface temperatures
- High level of comfort in the room climate and no draughts

Fig. 7 @ Fotolia

Simulation of thermal activated buildings

To ensure that a building fulfils comfort and energy efficiency requirements and therefore has pleasant temperatures even on the coldest or warmest day of the year, good planning and design of all the components required for the heat supply is required in advance. Conventional calculation methods are often based on simplifications and neglect important correlations for a correct and detailed calculation.

Particularly in connection with a thermal activated building system, conventional calculation methods, such as the standardisation on which the energy performance certificate is based or the standardised heat load calculation, do not produce practicable results in practice. One reason for this discrepancy is the thermal storage mass and its effect on the heating and cooling of buildings.

One remedy for the current lack of correct calculation methods is the use of simulation tools. With the help of simulations, individual components and systems through to entire flats or buildings can be examined in detail as required, the building technology can be optimised precisely to the needs of the respective building and, as a rule, oversizing can be avoided.

Based on the input on the climate, the component structures and the building services, the simulation can be used to figure out the room temperature, comfort, energy consumption of the entire building entire building or in detail of individual components. <<

Structure and functionality of a building simulation

A computer-aided simulation is based on a mathematical model that reproduces the real conditions and circumstances in a virtual environment. The increasing complexity of buildings, on the one hand due to the comprehensive requirements and on the other hand as a result of the wide range of technological possibilities available today, represents a major challenge for planners.

Simulation can significantly simplify this planning process and decisions about the design, building technology and other components can be made based on exact calculations.

Summer overheating, undersizing or oversizing of heating and cooling or other technical building systems, humidity problems, poor daylighting of rooms and similar problems can be avoided in advance through careful simulation. As a result, energy efficiency and comfort can be harmonised right from the planning stage and cost and time efficiency can be achieved.

Stationary calculations and dynamic simulation

A key difference between a detailed building simulation and stationary or quasi-stationary calculations is the time resolution of the calculation. While average monthly values are used in the monthly balance method in the energy performance certificate, for example, dynamic building simulation is often based on hourly input values. If necessary, however, smaller time steps are also possible. This means that in simplified procedures, hourly fluctuations in the outside temperature or solar radiation cannot be taken into account for the calculation.

The effect of the thermal storage mass can be considered in the dynamic simulation. <<

The dynamic analysis makes it possible to consider storage-effective masses and their effects over time. These dynamic effects are particularly important for inert systems such as TABs. If the temperature of the surface of the thermally activated component facing the room is higher than the room temperature, heat is transferred to the room. And this continues even if heat is no longer supplied to the component. This inertia of the system therefore creates a storage effect, which makes it possible to undercut the actual resulting heating load of a room or building when dimensioning and designing the heating system.

Figure 8 shows the temperature distribution of external TABs in a concrete wall with insulation over a period of 5 hours. The first image shows the initial state when the TABs is switched off (boundary conditions: Outside temperature = 0 °C, inside temperature = 22 °C, heating medium temperature = 35 °C).

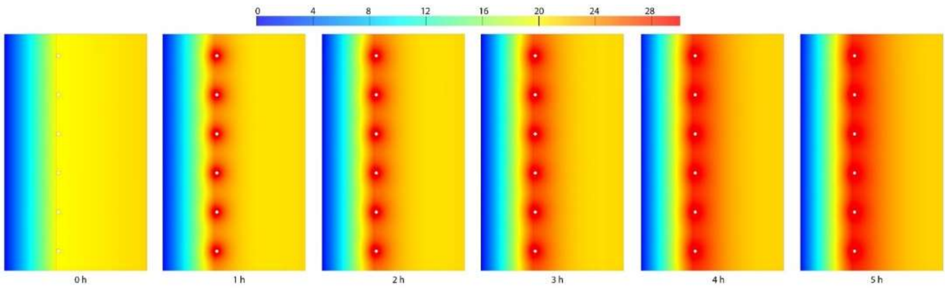


Fig. 8 **Dynamic heating behaviour of external TABs** in a concrete wall with insulation @FH Salzburg

Once the heat supply to the component-activated wall has started, it slowly begins to heat up until a steady state is reached after a few hours, provided that there is no change in the boundary conditions (e.g. external, internal or heating medium temperature). Until this stationary state is reached, the heat output increases steadily. Depending on the component structure, material and position of the pipework, it can take hours or even days in extreme cases for the component to heat up completely. In this example, even after more than 90 hours there is still an increase in heat output, with 80 % of the maximum output being reached after approx. 34 hours, as the simulation results show (Fig. 9).

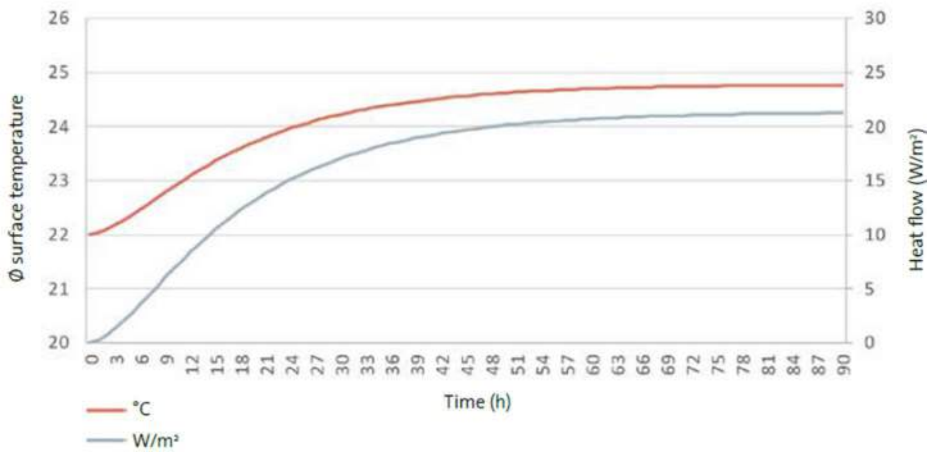


Fig. 9 **Average surface temperature and heat flow during** the heating process of the external TABs in a concrete wall over time @ FH Salzburg

If the heating is now switched off and the heat supply is stopped, the building component slowly cools back down to its original state. During this cooling process, heat continues to be continuously emitted into the room, whereby the heat output decreases over time. On a cold winter's day, for example, the dynamic simulation can now take into account the amount of heat stored in the building component in the hours before the minimum temperature occurs and thus reduce the necessary heating load.

With a detailed 2D simulation as shown in Fig. 10, individual systems can be examined and optimised in terms of their functionality and efficiency. For example, different types of attachment of the TABs to an existing external wall can be compared and the necessary heating medium temperatures to achieve a sufficient heat output can be determined.

> The building simulation can be used to determine the optimum heating curve and to develop various control strategies. <<

Fig. 10 shows a comparison of four installation variants for external TABs and the resulting heating of the component after 8 h and after 94 h of heating. The temperature distribution on the surface, the minimum and maximum temperature occurring, the heat output at different times, the losses of the TABs to the outside (if the TABs is located in a component of the thermal building envelope) or the division of the heat flows into two neighbouring thermal zones (if the TABs is located in an interior component such as a false ceiling) can also be determined.

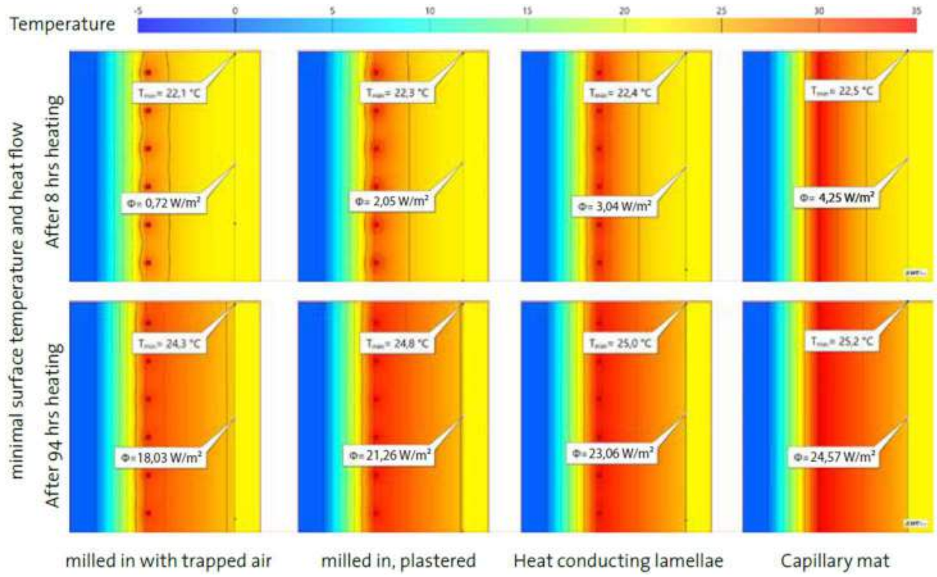


Fig. 10 Comparison of the **heat distribution of different variants of external TABs** in a concrete wall in the 2D simulation tool HTflux @ FH Salzburg

Depending on the simulation tool used, it is also possible to carry out hygric or sound insulation analyses in addition to thermal analyses. There is a wide range of programmes for different areas of application.

Component simulation versus building simulation

In addition to the simulations shown at component level, it is also possible to take a holistic view at flat or building level. While the former focuses on details such as the type of installation, the pipe spacing, the pipe diameter, the heat distribution in the component or the temperature ripple on the surface, more comprehensive building simulations usually involve higher-level analyses, for example with regard to comfort or energy efficiency.

In order to reduce both the time and effort required to create such a simulation, the TABs is usually modelled in a simplified way.

Some building simulation software maps TABs using the calculation method in accordance with EN ISO 11855-2. With this method, the detailed structure of the TABs is not modelled in the simulation, but instead an average temperature of the thermally conductive layer is used.

For this purpose, a distinction is made between the resistance in the pipe level (includes influences of the pipe type, the pipe level, the water flow and the resistance of the heat-conducting layer in which the pipes are located), and the resistance between this heat-conducting layer and the room (includes the resistance of the individual layers above/below the pipe as well as the heat transfer resistances at the surface).

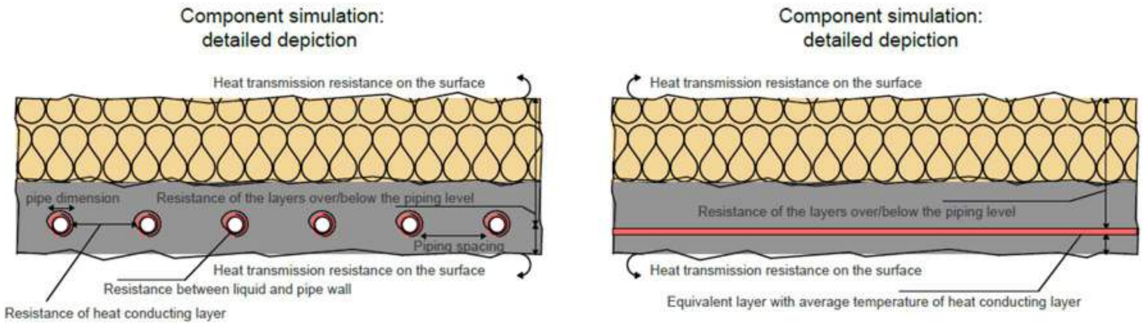


Fig. 11 **Schematic comparison** of the mapping of a thermal activated building system in a detailed building component simulation and the simplified mapping in the building simulation according to EN ISO 11855-2 @ FH Salzburg

This average temperature of the heat conducting layer can be R_t established using the basis of the flow temperature and the resistance in the piping level. Hereby the resistance R_t can be calculated using the following formula:

$$R_{\mathrm{t}} = R_{\mathrm{z}} + R_{\mathrm{w}} + R_{\mathrm{r}} + R_{\mathrm{x}}$$

Hereby

R_{t} is the resistance between the flow temperature θ_v and the average temperature in the heating conducting layer$\bar{\theta}_e$ in $(\mathrm{m}^2 \cdot \mathrm{K})/\mathrm{W}$

R_{z} the fictitious resistance between the flow temperature θ_v and the average heating source temperature in $(\mathrm{m}^2 \cdot \mathrm{K})/\mathrm{W}$

R_w the resistance between the liquid and the pipe wall $(1/h_w)$, in $(\mathrm{m}^2 \cdot \mathrm{K})/\mathrm{W}$

R_r the resistance of the pipe wall, in $(\mathrm{m}^2 \cdot \mathrm{K})/\mathrm{W}$

R_x the resistance between the temperature and the outer piping side and the average temperature of the heat conducting layer in $(\mathrm{m}^2 \cdot \mathrm{K})/\mathrm{W}$

If TABs are to be depicted in the building simulation this resistance must be known and calculated. If this is known, further input is no longer particularly time-consuming. Alongside the resistance, the corresponding areas to be activated and the location of the piping (spacing to the structure surface) must be established for the thermal activation as well as the design capacity.

> The cost of this simulation can quickly pay for itself if it enables a more efficient design of the TAB of the TAB becomes possible. <<

Hereby it is important to note that the given area of the TABs corresponds to the actually activated area and that any outer areas in which there isn't any piping are deducted. A concrete detailing of the location is equally important. With materials with low heat conducting ability, in particular, the location of the piping has a considerable influence on the possible heating and cooling capacity.

Alongside the parameters of the thermally activated building it is also important that the heat generating system in the building simulation is orientated to the thermal activation. Empirical values show that in many cases in thermal activation a flat heating curve and consequentially lower flow temperatures than with underfloor heating, as an example, are possible. The building simulation can also examine various control and regulating strategies and their effect on energy requirements as well as the efficiency of the system. With time-delay and storage related systems a smoothing of the input parameters over several hours is recommended (for example a smoothing of outside temperature with outside temperature led flow temperature regulation). Due to the thermal storage masses, a reaction to a change of the boundary conditions is only very time delayed. If this time delay and inertia is not taken into consideration the control system may start to oscillate. Here smoothing can ensure even heat emission to the component and, as a result, the room and prevent the oscillation of the heating.

To sum up, building simulation offers many benefits and enables an examination of innovative concepts and systems which would otherwise be difficult or impossible to illustrate. In association with thermally activated building, in particular, building simulation is standard practice and imperative in many cases. To obtain targeted results and avoid unnecessary effort, it is advisable to formulate specific questions in advance that are to be answered by the simulation. This ensures cost and time efficiency in planning.

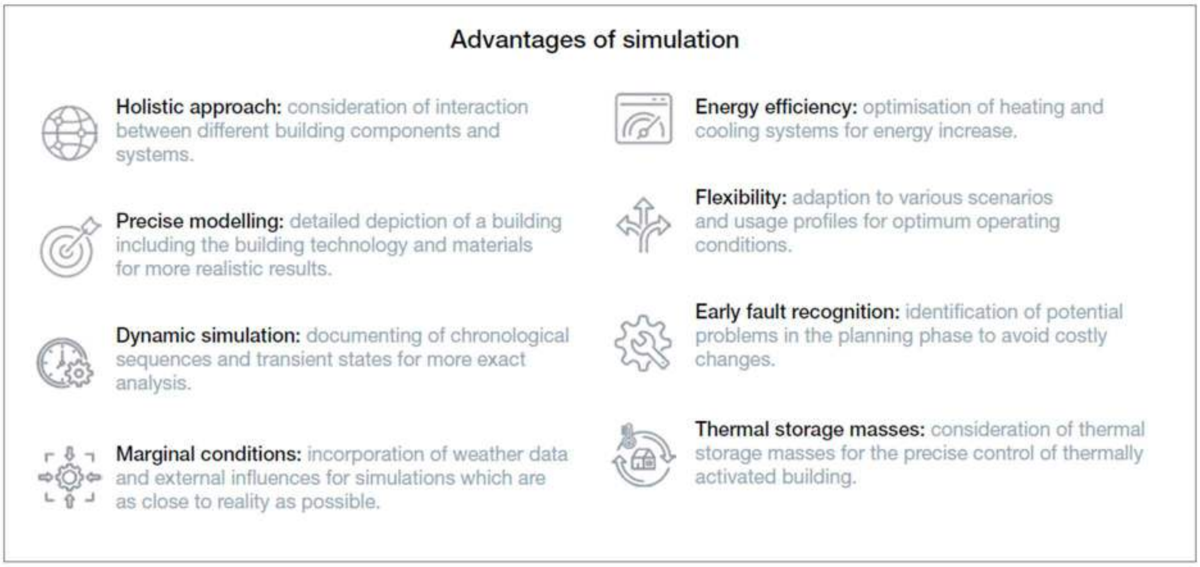
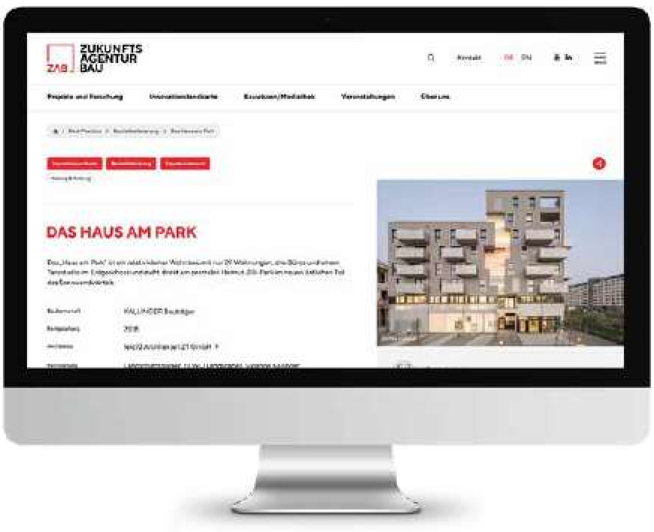


Fig. 12 **Advantages of simulation** @ FH Salzburg

Where can I find information on projects that have already been successfully implemented

The innovation map of the ZAB Zukunftsagentur Bau offers a collection of of innovative construction projects in various subject areas. Over 120 projects from 4 countries have already been entered on the topic of ‘thermal activated building systems’.
The projects range from refurbishments with retrofitted pipes and the construction of new apartment blocks to public buildings such as schools, university buildings and offices.

For each project there is an info box with the most important data, a few photos and a short description. This gives you a good overview of the many possibilities of thermal activated building systems, details worth knowing, companies carrying out the work or experts involved!
www.zukunft-bau.at/innovationslandkarte



Where can I find more details on TABs systems?

Project page Interreg Alpine Space project
« alpine-space.eu/project/coolalps

FactSheet Climate and Energy Fund
« klimafonds.gv.at

Planning guide for TABs systems
« zement.at

Salzburg University of Applied Sciences
« fh-salzburg.ac.at

Project partners

ZAB Future agency of construction
« zukunft-bau.at

Agency for Energy South Tyrol - KlimaHaus
« klimahaus.it/

BI Bavaria innovative GmbH
« bayern-innovativ.de/de

BETONSUISSE Marketing AG
« betonsuisse.ch

Innovation Salzburg GmbH
« innovation-salzburg.at

Technical university Rosenheim
« th-rosenheim.de

Salzburg University of Applied Sciences (as part of the development of the information sheet)
« fh-salzburg.ac.at

Interreg Alpine Space Co-funded by the European Union | Cool*Alps

This project is co-funded by the European Union through the Interreg Alpine Space programme.