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ROOM-INTEGRATED LARGE HOT WATER STORAGE

Summary

The running project revolves around examining an old porcelain factory and planning an innovative energy supply system for the quarter. Two CHPs and an ORC already exist there and are used for power generation. Their waste heat is used for heating the 40,000 m² large building now used as a commercial area with a large number of tenants. To be able to store the waste heat for phases of large heat demand, the concept of a room-integrated hot water storage is part of the research done in the project. The walls of the room serve as static limits for the storage. They will be insulated and sealed to prevent moisture penetration of the insulation. The remaining space is then filled with 1,300 m³ of water. Temperatures up to 95 °C should be possible. The first step will be the investigation of appropriate materials for insulation and sealing. Simulations regarding the heat supply system and the heat transfer through the walls as well as a CFD simulation provide the basis for choosing the best storage concept and suitable components e. g. for temperature stratification in the room.

Keywords: Storage, hot water, insulation, sealing, refurbishment, CFD, modelling

1. Introduction

In the running project, a high share of renewables in the power and heat supply is planned for an over 100-year-old porcelain factory. After the decline of the porcelain industry in Upper Franconia in the 1990s, the quarter was decaying, but it is now reactivated. It is rented out to different companies and simultaneously refurbished. The municipal utilities provider operates two biogas-fired CHPs and an ORC in the building, used for grid feed-in. Their waste heat is sold to the real estate company owning the quarter and serves for the building heating. To be able to store the heat for phases of large demand, the concept of a room-integrated hot water storage is part of the research work in this project.

2. Starting point

At the moment, the heat of the CHPs and ORC is used to heat the 40,000 m² large building. Surplus heat is dispensed over an external dry cooler and thus wasted. In the future, it is supposed to be buffered in a large hot water storage with a volume of 1,300 m³, directly integrated into a cellar room. This cellar formerly served as a storage for porcelain to be delivered, but is currently not in use. It was built in the 1970s and can bear high weight loads due to its former purpose. This makes it a good candidate for transformation into a large heat storage. Figure 1 shows the 550 m² cellar.

Fig. 1: Cellar with bearers and columns which is to be transformed into a hot water storage [Source: Own illustration]

If the CHPs and the ORC are running in full load, they provide 500 kW_{th} heat at a maximum temperature of 85 °C. As the biogas is coming from a nearby yeast factory, its production is undergoing some fluctuations. This means it is rather unusual that all three generators are running simultaneously. For times of high heat demand, a 500 kW condensing gas boiler is installed as a backup. The large building and further planned new buildings on the area have a future heat demand of 3.9 GWh. Based on a temperature spread of 545 K, the cellar would provide an additional thermal storage volume of 83 MWh, which could support the generation units by buffering high peaks of heat demand.

3. Project content

A room-integrated hot water storage of such size has never been built. Thus, a lot of aspects from structural design, material resistances, heat transfer inside the storage and to the surroundings, up to fluid flow have to be investigated and tested in experimental setups. Further topics like economic feasibility and legal aspects need to be considered but are not part of this abstract.

The geometry of the cellar does not correspond to the standard shape of a heat storage with a good A/V ratio like e. g. the seasonal storage at Ackermannbogen in Munich with its shape approximated to a sphere (Dallmayer et al., 2010). At a height of only 2.9 m, the room has a rather low ceiling for a storage application. Furthermore, bearers and columns were necessary to stretch the construction when the room was built. For the storage purpose, these features are challenging and need to be investigated. On the other side, three walls are touching the ground and only one wall is in contact with the ambient air. Regarding statics, this is advantageous, just like the fact that the room is rather large in volume. Combined with a good insulation, this should counterbalance the unusual A/V ratio. Figure 2 shows the wall structure of the cellar after the transformation into a heat storage. An interior insulation followed by a sealing layer protects the reinforced concrete walls as well as the rooms one floor above from high temperatures and moisture. An exterior insulation is installed to prevent building damage.

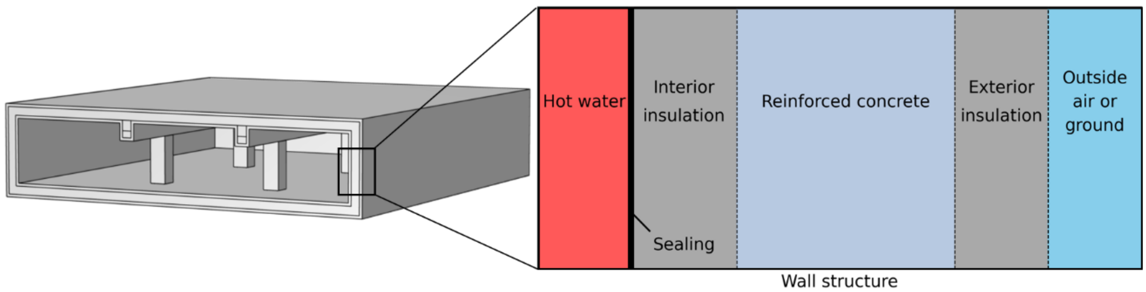

Fig. 2: Left: Sectional view of the 3D model of the cellar, right: Wall structure after transformation from concrete wall to heat storage [Source: Own illustration]

To ensure good interior insulation of the storage, different materials are evaluated and tested in lab experiments regarding their thermal conductivity and long-term stability. Sustainability and cost are essential aspects for the application, too. Since it is an important part of the project to consider the entire lifecycle of a product, recycled or natural materials would be preferable to conventional insulating materials. The advantages of sustainable materials are demonstrated by Hill et al., 2017 and Sierra-Pérez et al., 2016. In contrast, conventional insulating materials often combine low thermal conductivity and low cost (Villasmil et al., 2018).

Moreover, long term stability of the insulating and sealing material plays a major role in reaching the targeted storage lifetime of up to 50 years. Temperature and pressure resistance have to be taken into account. Also, the building walls and insulating material must be protected from water as well as water vapor entering from the storage side. Next to commonly used stainless steel, there are different types of plastics that may be suited as sealing materials. But especially there, aging caused by temperature stress is a problematic influence on the tightness of the plastic sealing (Wilhelms et al., 2010). Dallmayer et al., 2000 and Simmler et al., 2020 already worked on similar tasks by building a sealing system for integration into an existing tank and room-integrated storage, respectively, with water temperatures up to 60 °C. However, the thermal stress on the lining was much smaller due to lower water temperatures.

Apart from material investigations, the concept of the hot water storage is examined in simulations. A POLYSUN model is designed to see effects on thermal energy supply due to the large storage, focusing on the hydraulic integration and control of the system. Since the existing large building and further planned new buildings in the quarter combine an increasing heat demand and much higher thermal peak load, the current generating units might need to be extended by other heat sources, e. g. solar thermal collectors. That is why the storage might need to be designed for temperatures up to 95 °C.

A simulation of the charging and discharging process as well as the heat transfer through the insulation and walls is performed with a COMSOL Multiphysics model. Different designs of stratification devices as well as the possibility to divide the room into several chambers with assigned temperature levels are evaluated concerning their effect on thermal stratification. 3D heat transfer simulations within the cellar are performed and will show the heat's impact on the reinforced concrete walls and ceiling of the cellar. The effect on the entire building's statics will be investigated. As can be seen, there are various aspects in need of examination before building the first demonstrator of this new type of thermal energy storage.

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4. Outlook

The next steps will be testing different insulation and sealing materials under approximated real conditions of the storage application. A demonstrator of several cubic meters will show the feasibility of the concept. Furthermore, a control strategy needs to be designed and low return temperatures from the heating system in the building must be guaranteed. Economic calculations must be carried out with differing boundary conditions to showcase the advantages of such a large storage. After thorough testing of the setup, the heat storage is supposed to be built in a planned follow-up project in about two years. Long-term monitoring will show the efficiency under different operational conditions and reveal further optimization potential for this new type of thermal energy storage.

5. References

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