SEASONAL HOT WATER HEAT STORE WITH SELF-SUPPORTING SHELL COVER

F. Ochs
Institute of Thermodynamics and
Thermal Engineering (ITW) University of Stuttgart
Pfaffenwaldring 6
D-70550 Stuttgart, Germany
ochs@itw.uni-stuttgart.de

A. Lichtenfels
Ingenieurbüro Lichtenfels
Bergstr. 11
D-75310 Keltern, Germany
achim.lichtenfels@lichtenfels.li

W. Heidemann
Institute of Thermodynamics and
Thermal Engineering (ITW) University of Stuttgart
Pfaffenwaldring 6
D-70550 Stuttgart, Germany

H. Müller-Steinhagen
Institute of Thermodynamics and
Thermal Engineering (ITW) University of Stuttgart
Pfaffenwaldring 6
D-70550 Stuttgart, Germany

ABSTRACT

A new self-supporting cover for seasonal hot water stores has been developed. It is installed at the Institute of Thermodynamics and Thermal Engineering (ITW) as shell cover with prefabricated sandwich elements made of high-performance concrete with PUR core. Due to the significantly higher strength of the high-performance concrete very thin units can be produced. In contrast to conventional self-supporting covers for the construction no scaffolding and hence no foundation is required. Reduced material usage and consequently reduced primary energy demand for construction is a further advantage of this concept.

1. INTRODUCTION

Seasonal storage of solar thermal energy or of waste heat from heat and power cogeneration plants will significantly contribute to substituting fossil fuels in future energy systems. Where the geological situation does not allow for the construction of a borehole thermal energy store (BTES) or a aquifer thermal energy store (ATES), a seasonal heat store can be constructed either as pit or as tank heat store. Dimensions of pilot and research tank and pit heat stores range from some 100 m³ up to more than 10 000 m³.

2. GRAVEL WATER VS. HOT WATER HEAT STORE

Pit heat stores are constructed without further static means by mounting insulation and a liner in a pit. According to their storage medium seasonal heat stores are distinguished into gravel-water heat stores, soil/sand water heat stores or hot water heat stores. Both tank and pit heat stores may be constructed as hot water stores or as gravel or soil/sand water heat stores. However, until now only pit heat stores have been built as gravel water heat stores (GW) or soil/sand water heat stores (SW).

The hot water (pit) heat store is preferable in terms of thermal capacity and operation characteristics. Due to the improved dynamic behaviour compared to the other seasonal heat store types, the integration of a hot water store in the heating system is less problematic, i.e. no additional buffer store is required. In case of leakage, a hot water store may be repaired, whereas it may be more economic to build a new gravel water pit heat store depending on required maintenance and repair.

TABLE 1: Storage medium: gravel-water vs. water

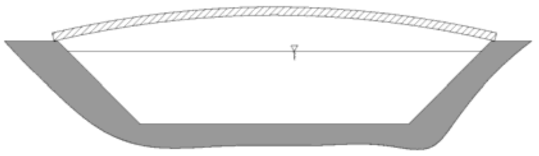
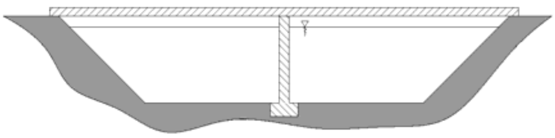
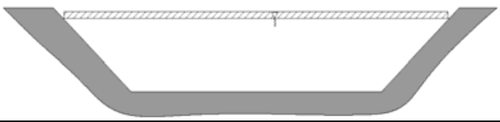
hot water pit heat store	**gravel water pit heat store**
+ thermal capacity + operation characteristic (dynamic) + stratification + maintenance/repair	+ statics (load nearly unlimited) + simple cover
– complicated and expensive cover – safety (damage) – costs for landfill of excavated soil	– thermal capacity (66 %) – charging system (indirect charging) – operation characteristics (slow, additional buffer) – no maintenance/repair – gravel costs

Gravel or soil/sand water pit heat stores are only advantageous, if static concerns are of major importance as in the case of the gravel water pit heat store in Chemnitz [1, 2], where a parking lot has been built on top of the store. A cover for a hot water store with comparable static characteristics requires enormous technical and financial efforts.

3. Cover for Hot Water Stores

For hot water stores three types of covers may be distinguished. Self-supporting (shell shaped) covers, supported covers and floating covers. The advantages as well as the limits and constraints of these covers are summarized in table 2.

TABLE 2: Cover Types for Hot Water Stores

self-supporting cover

+ accessible/trafficable + store is accessible/maintainable – complex/expensive construction – relatively high construction (pass) limited storage volume/surface area
supported cover

+ accessible/trafficable + store is accessible/maintainable – penetration of liner at bottom – high mechanical load on column (foundation slab required) – cold bridge at column on top and on bottom
floating cover

+ simple cost-effective construction + unlimited surface area (for buoyant cover) – limited accessibility/trafficability – limited/no store accessibility (maintenance /repair) limited space for charging system – complex construction of charging system charging (for buoying cover)

The economic benefit of a floating cover in comparison to a self-supported cover is obvious. However, with regard to traffic restrictions, the self-supported cover should be aimed at. At least one of each type has already been realized in research or pilot heat stores.

The main disadvantage of realized self-supporting covers of hot water pit heat stores is that due to the required mechanical strength massive elements have to be build. The cover of the tank heat stores in Friedrichshafen and Hannover have been built with in-situ concrete with a thickness of 25 cm [2, 3, 4]. The tank heat store built in 2006/2007 in Munich is the first with a cover made of prefabricated elements. The thickness of the concrete layer could be reduced. However, it has still a thickness of 18 cm [5]. A further disadvantage of these covers is that a major share of the construction cost arises due to the need for complex scaffolding and foundation.

4. Self-supporting Cover

The aim of future developments is the construction of a self-supporting cover with reduced material usage and consequently reduced primary energy demand. The cost should be comparable to realized projects or even be reduced. In contrast to conventional self-supporting covers no scaffolding and hence no foundation should be required for the construction.

4.1 Construction of the Sandwich-elements

The suggested cover consists of prefabricated sandwich-elements made of high performance concrete with PUR core. Due to the significantly higher strength of the high-performance concrete very thin units with a thickness of only few centimetres can be produced, see [6]. Application of high performance concrete for tank heat stores has been investigated in [7] in detail. The tank realized in 2000 in Hannover is made of high performance concrete [4]. Hence, experiences gained during construction and operation of the tank heat store could be used. The production of the sandwich-elements is schematically shown in fig. 1.

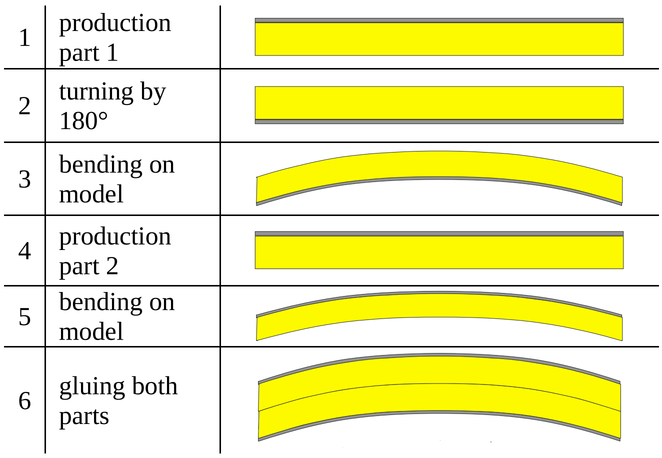


Fig. 1: Production process of the prefabricated sandwich elements

The sandwich concept could be proven in preliminary tests where elements with 2 cm reinforced high performance concrete on 16 cm PUR sheets have been used [8]. However, the tests showed that it is advantageous to produce the two parts of the sandwich-element using different thickness of the PUR-layer. Due to high tensions in the lower part during the bending, there is a risk of crack formation in the PUR layer. The bending of the upper part is less critical as the PUR layer is compressed during bending. Hence, for the research store a total PUR core thickness of 32 cm consisting of 4 cm of the lower part and of 28 cm of the upper part, respectively have been used, see fig. 2.

Fig. 2: Sandwich element mounted on the pit, static (human) load test

4.2 <u>Construction of the Cover</u>

The cover of the research pit heat store at ITW has been built as shell cover using three elements with a width of 2m and four elements with a width of 1m. The shell cover is completed on the sides with bulk heads. The construction sequence is schematically illustrated in fig. 3.

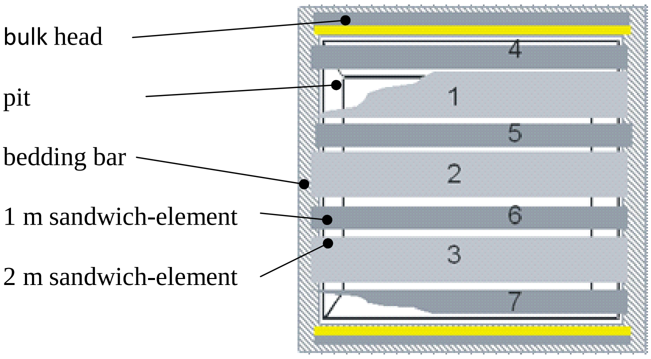


Fig. 3: Construction sequence of the self-supporting cover

In order to guarantee a water and water vapour proof construction the cover is sealed with an Al- HDPE composite liner, which is fixed to the elements by small steel anchors (see fig. 4).

Fig. 4: Sandwich element with liner is moved by truck mounted crane

A major feature of the concept is the construction without scaffolding. Hence, a procedure has been developed that allows for the welding of the liner from the top of the cover (see fig. 5 and 6).

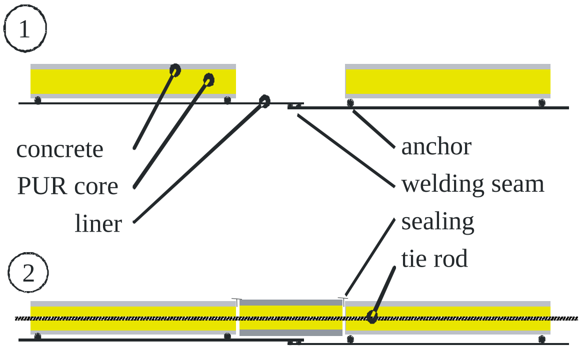


Fig. 5: Schematic sketch of the self-supporting cover

Fig. 6: Welding of the composite liner between two elements from the top of the cover

After the welding, the 1m wide elements are placed into the cavity. Optionally, the mechanical strength of the construction could be enhanced by prestressing with tie rods.

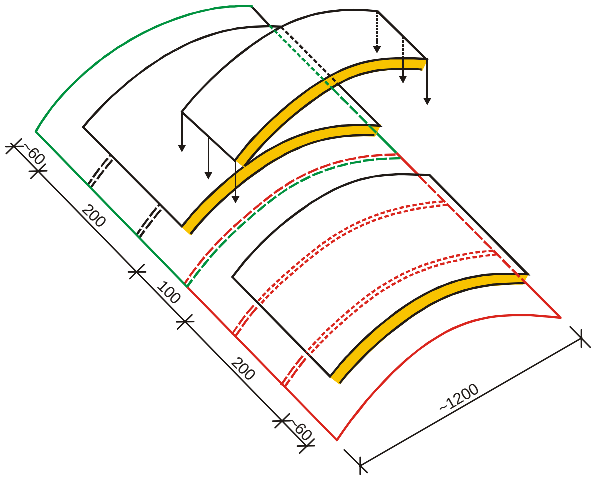


Fig. 7: The smaller 1 m wide elements are placed in the cavity after the welding of the liners

The liner of the cover is welded to the liner of the pit externally at the edge of the store. Thus, again no scaffold is required.
The completion of the construction is still to be done. In fig. 8 the current state of the cover of the research store is shown.

Fig. 8: Sandwich elements on the pit.

The remaining steps after welding the liner between the elements from the top side of the lid include the installation of the 1 m wide elements and the two bulk heads.

5. CONCLUSIONS

Hot water heat stores offer substantial advantages over gravel water heat stores. However, the construction of a cover for hot water heat stores is complex and consequently costly. With the suggested sandwich construction no scaffolding and hence no foundation is required for the construction process. Compared to conventional self-supporting covers reduced material usage and consequently reduced primary energy demand for construction is one main advantage of this concept.
Technical feasibility of the concept has been demonstrated at ITW. The cover is equipped with temperature and heat flux sensors. Measurements of the thermal and mechanical behavior will soon be available.

4. ACKNOWLEDGMENTS

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