

# Effect of an additional accumulation wall on course of interior temperatures in a light modular construction

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**Abstract.** This paper is focused on influence of an additional concrete wall on indoor temperature in the light modular construction. Typically, there are no accumulation materials used in these constructions. The study was based on measurements obtained from a full-scale experimental set-up built for this purpose. Two identical modular constructions were used; one of them was equipped with an additional concrete wall. Indoor temperatures were measured in the course of time and compared.

## 1. Introduction

Evaluation of heat accumulation is very important in case of modular constructions that are permanently used as residential buildings. Light modular constructions with low heat accumulation started to be popular after the First World War [1] but the heating mode remained the same as for the brick houses, i.g. with night declines. As a consequence, the light constructions quickly cool down. This was an impulse that started evaluation of heat accumulation of perimeter walls. It is important to bear in mind that the temperatures in the buildings and walls are changing with time. The real temperatures of the constructions are always variable, unstable.

## 2. Description of the light modular constructions

The study was based on measurements obtained from a full-scale experimental set-up built for this purposes. Two identical light modular construction, on Figure 1, were compared; one with a concrete accumulation wall and the other without any additional wall.

The modular construction has standard dimensions (length is 6,058m, width is 2,990m, height is 3,010m) and it can be carried by a truck. There are two triple glass insulated windows and one entrance door. Inside is an electric heater which is controlled manually.





**Figure 1.** Two light modular constructions used for the experiment

A concrete wall from from dry-concrete paving stones was built in one of the modular constructions, Figure 2. Thanks to two different set-up, it was possible to compare the course of interior temperatures in both constructions.



**Figure 2.** Construction of the concrete accumulation wall

### 3. Thermal resistance of the perimeter constructions

When choosing the material of perimeter walls, it is desirable to select a material with the highest value of thermal resistance  $R$  [ $\text{m}^2\text{K}/\text{W}$ ] so that the heat loss would be the smallest possible. The value of thermal resistance depends on thermal conduction and on the thickness of individual layers of the wall construction, but it is not depending on accumulation abilities of the used materials [2].

Nevertheless, accumulation ability of the material is one of the crucial factors that influence thermal comfort in the building, both in summer and winter. While assessing thermal resistance of a material, there is an assumption that the temperature on both sides of the construction is constant in time [3]. However, this scenario is rare since the indoor and outdoor temperatures are variable in time.

The temperature of air outside of the construction is affected by many attributes; changing of day and night, changing of seasons or changing of intensity of solar radiation. The temperature inside of the construction is affected by discontinuous heating, ventilation or by immediate changes in the environment.

Evaluation of heat accumulation of perimeter constructions is important when deciding if the heating in the building is going to be continuous or discontinuous [4]. If discontinuous mode is chosen, the temperature of indoor air as well as the surface temperature of the constructions are decreasing while the heating is off. The value of the temperature decrease during the heating break is assessed by criteria called thermal stability of a room during winter [5].

#### 4. Properties of the accumulation wall

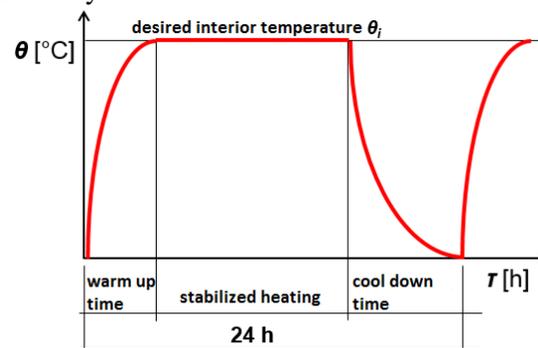
The accumulation wall was built in one of the two light modular constructions from dry-concrete paving stones. The thickness of one paving stone was 100mm. While considering the accumulation properties of the accumulation wall the maximum width of would be 150mm; thicker wall will not show significantly better results [6].

**Table 1.** Properties of the accumulation wall.

	Units	
material	-	<b>concrete</b>
thickness	(mm)	<b>100</b>
density	kg/m <sup>3</sup>	<b>2100</b>
specific heat capacity	J/kgK	<b>1020</b>
thermal conductivity	W/mK	<b>1,23</b>

#### 5. Course of temperature

Data from this experiment were collected in 2015 during winter. Each light modular construction was equipped with an electric heating that was turned on an off controllably. The daily cycle, on Figure 3, started in the morning when the heater was turned on. Specific amount of time is needed to warm up the interior air on desired temperature. During the day, the heating is maintaining the temperature on a stable level. During the night, the heating is turned off and the temperature is dropping. The cycle starts again in the morning next day.



**Figure 3.** Daily cycle of course of temperature in a room with discontinuous heating

## 6. Results

### 6.1. Time needed for warming up interior temperature

The heating in the two light modular constructions was turned off for several days so the initial indoor temperature was the same in both objects. After the heating was turned on, temperature increase was monitored. As compared on Figure 4,5,6, the experiment was repeated three times always with different course of exterior temperature. It is obvious, that the light modular construction with the accumulation wall needs longer time to warm up the interior on a desired temperature. Depending on exterior temperature, the needed time to warm up the interior was between four to six hours. The desired interior temperature in the construction without any accumulation wall was usually reached in two to four hours.

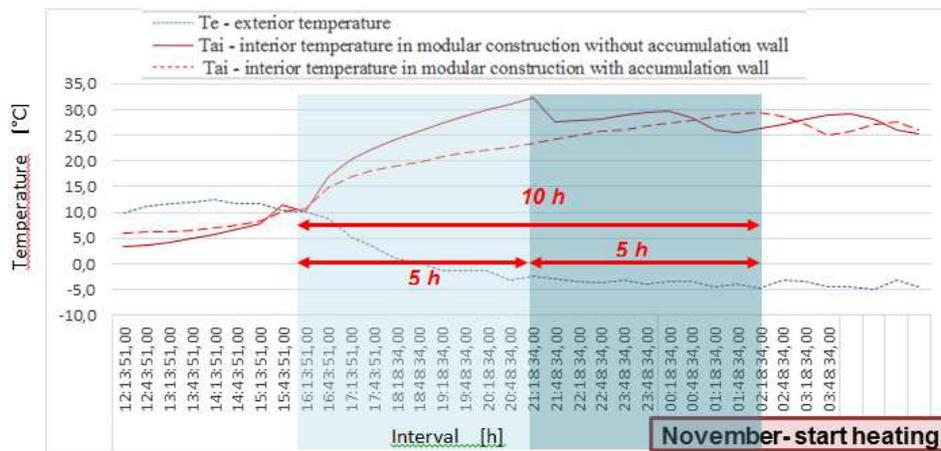


Figure 4. Time needed to warm up indoor temperatures in the constructions and the course of outdoor temperature in November 2015

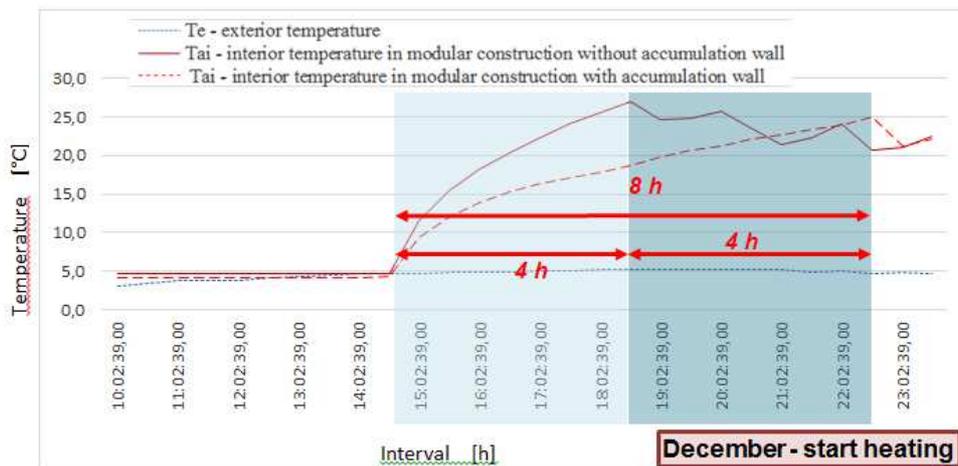


Figure 5. Time needed to warm up indoor temperatures in the constructions and the course of outdoor temperature in December 2015

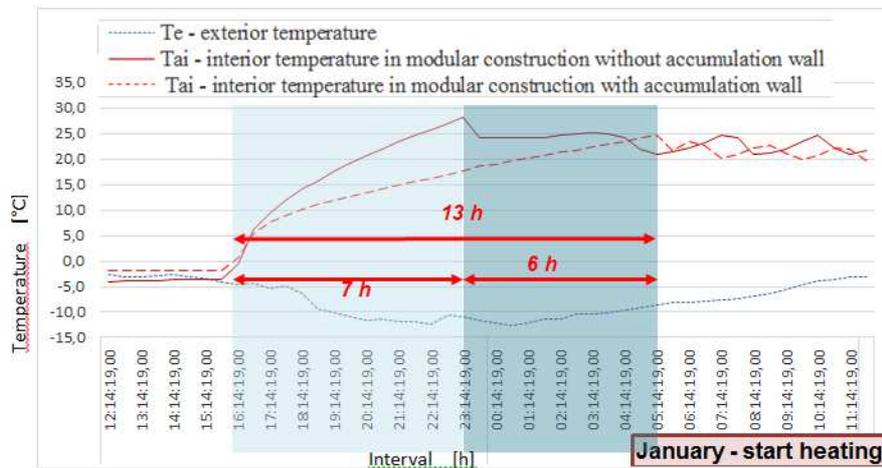
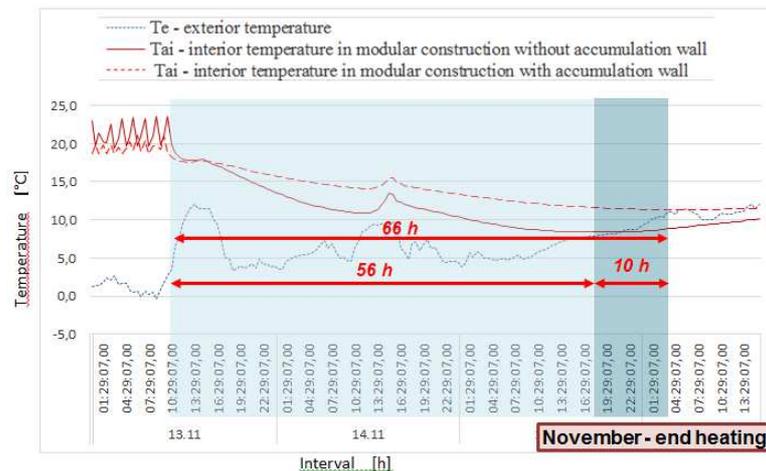


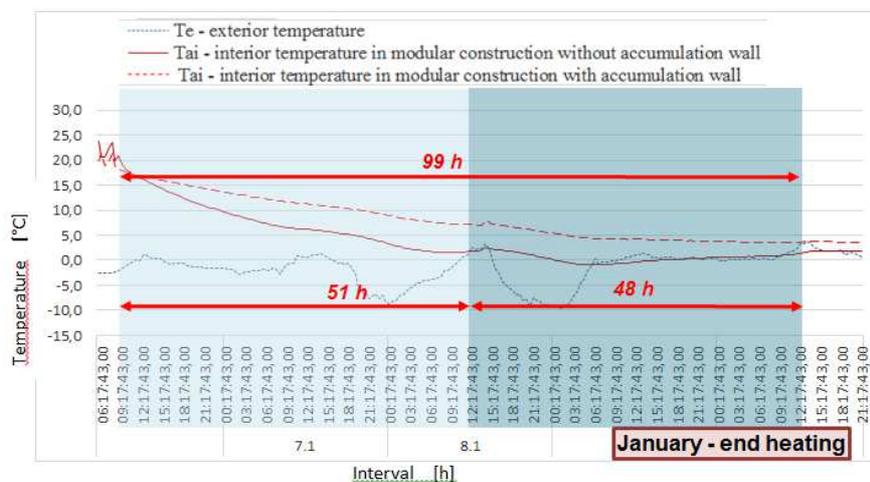
Figure 6. Time needed to warm up indoor temperatures in the constructions and the course of outdoor temperature in January 2016

### 6.2. Time needed to cool down the interior temperatures

Time needed to cool down the interior temperatures after the heating is turned off depends on the course of exterior temperatures and on the amount of accumulated heat in accumulation constructions. As it was observed, Figure 7,8, on the set-up, the interior temperature was equal to exterior temperature in shorter time in the light modular construction without any accumulation wall.



**Figure 7.** Time needed to cool down indoor temperatures in the constructions and the course of outdoor temperature in November 2015



**Figure 8.** Time needed to cool down indoor temperatures in the constructions and the course of outdoor temperature in January 2016

## 7. Conclusion

The comparison of the course of interior temperatures in two light modular constructions showed that the concrete accumulation wall has a significant impact on the cooling time. The light modular construction without any accumulation wall was warmed up/cooled down faster than the light modular construction with the accumulation wall. Buildings without any accumulation constructions are suitable for short-time use, when the heating is running continuously and when quick cool down of the indoor temperature is of small importance.

Nevertheless, if the light modular construction is meant for long term residential use it is more than desirable to integrate an accumulation construction. Such construction will raise thermal comfort in the building if the heating is discontinuous. The accumulation wall is balancing the indoor temperature more smoothly and if the heating discontinuity is controlled, it can lead to energy savings and therefore money savings. This aspect is going to be even more noticeable in so called zero buildings, where the heating is depending on direct demand of power from a local (renewable) source, e.g. solar power.

## 8. References

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