

# Natural ventilation in underground wine cellars

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## Abstract

The main objective of this research is to promote passive thermal design techniques in the construction of wineries. Natural ventilation in underground cellars is analyzed, focusing on the entrance tunnel, the ventilation chimney and the cave. A monitoring system was designed in order to detect changes in the indoor conditions and outdoor air infiltration. Monitoring process was carried out during one year. Results show the influence of outside temperature, ventilation chimney and access tunnel on the conditions inside the underground cellar. During hot periods, natural ventilation has a negligible influence on the indoor ambience, despite the permanently open vents in the door and chimney. The tunnel and ventilation chimney work as a temperature regulator, dampening outside fluctuations. Forced ventilation is necessary when a high air exchange ratio is needed. During cold periods, there is greater instability as a result of increased natural ventilation. The temperature differences along the tunnel are reduced, reflecting a homogenization and mixing of the air. The ventilation flow is sufficient to modify the temperature and relative humidity of the cave. Forced ventilation is not necessary in this period. During the intermediate periods --autumn and spring-- occurs different behaviors based on time of day.

**Key words:** underground construction, ventilation, tunnel, chimney.

## 1. Introduction

The literature on winemaking points out the importance of a constant low temperature inside buildings where wine is stored, in order to produce a high-quality end product as well as to reduce wine losses (Martin & Canas, 2006). Underground wine cellars have been in use for centuries for making and ageing wine. The temperature inside underground cellars is fundamentally conditioned by the ground and the outside air temperatures which enter the cellars as a result of the ventilation (Cañas & Mazarrón, 2009; Mazarrón & Cañas, 2009). The control of interior conditions will allow to achieve a better quality wine and smaller losses by evaporation without need of air conditioning, which, given the long ageing interval could translate into great energy expense (Mazarrón et al., 2012).

In this research we analyze the natural ventilation in underground cellars, focusing on the entrance tunnel, the ventilation chimney and the cave. We analyze how the differences between indoor and outdoor temperature influence natural ventilation.

## 2. Materials and Methods

To carry out the study, a typical underground wine cellar, located in Spain, was selected. A monitoring system was designed to analyze the natural ventilation and the ambience inside the cave, tunnel and chimney. 57 temperature sensors (precision  $\pm 0.2$  °C in the range 0-50 °C; resolution 0.02 °C at 25 °C) and 37 humidity sensors (precision  $\pm 2.5\%$ rh from 10 to 90%;

resolution 0.03% rh) were distributed all over underground construction in order to detect changes in the indoor conditions and outdoor air infiltration (Fig. 1). Monitoring process was carried out during one year, from April 2011 to March 2012.

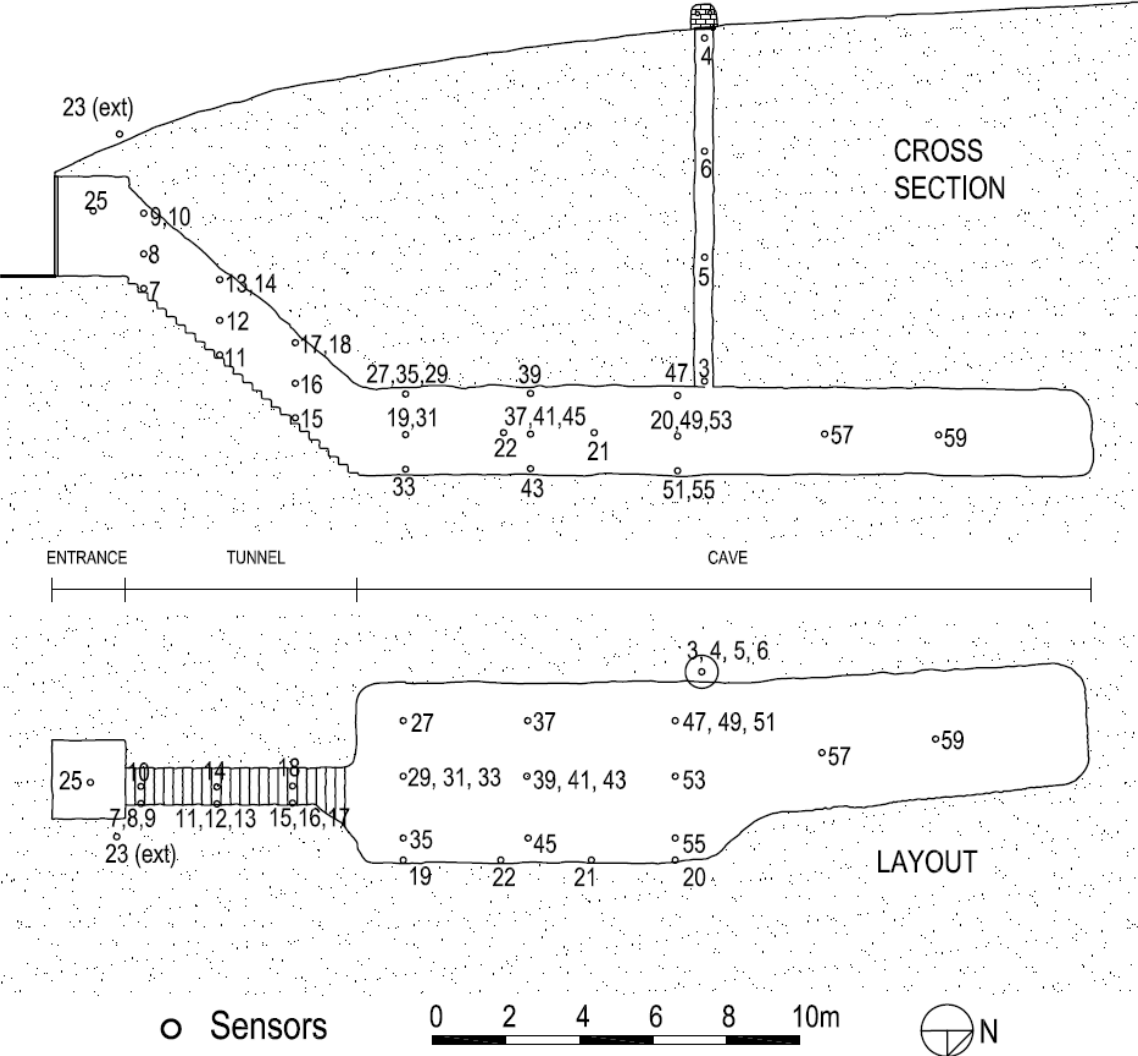


FIGURE 1: Cross section and layout of the underground wine cellar. Position of the sensors

**3. Results and conclusions**

**3.1. Hot periods**

During hot periods, natural ventilation has a negligible influence on the indoor ambience, despite the permanently open vents in the door and chimney. The tunnel and ventilation chimney work as a temperature regulator, dampening outside fluctuations. The differences between the beginning and end of the tunnel can exceed 10°C. In ventilation chimney happens the same.

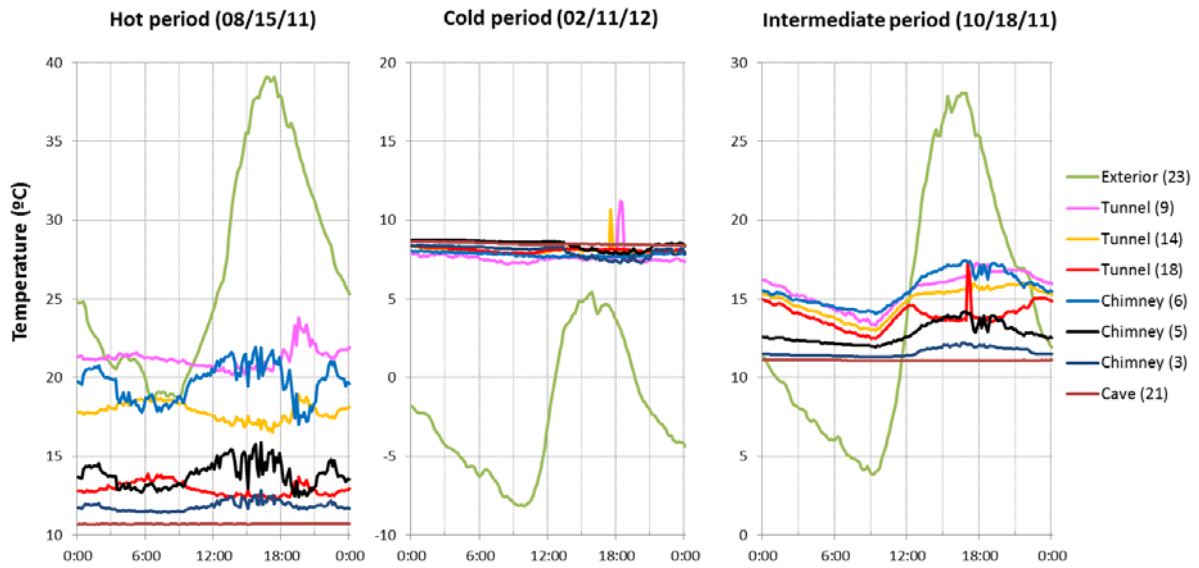


FIGURE 2: Temperature in different parts of the tunnel, ventilation chimney and cave, in representative days during the hot, cold and intermediate periods

The air seems stratified according to the ground temperature, becoming more stable as the depth increases (fig. 2 and fig. 3). Specific entries of hot air occur through the door, causing the cave indoor air outlet through the ventilation chimney.

Nevertheless, the ventilation flow is not sufficient to affect the temperature or relative humidity of the cave. Temperature differences between the different parts of the cave and the ground rarely exceed 0.5 °C (Fig. 4).

Due to this behavior, forced ventilation is necessary when a high air exchange ratio is needed.

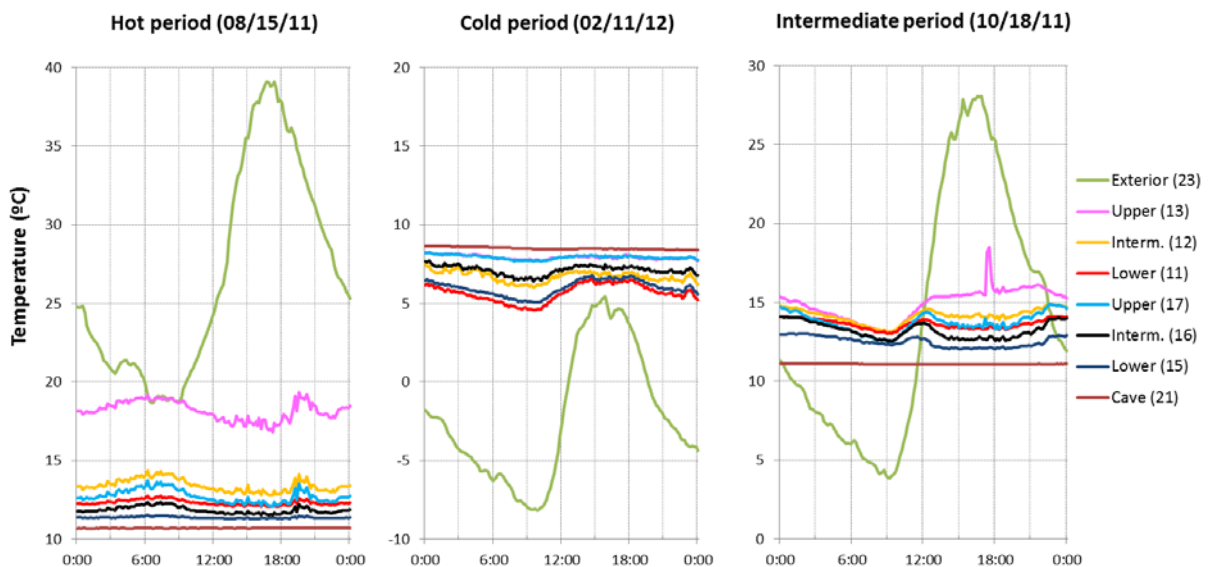


FIGURE 3: Temperature stratification according to the different parts of the tunnel in representative days during the hot, cold and intermediate periods

### 3.2. Cold periods

During cold periods, when the outside temperature drops below the indoor temperature, there is greater instability as a result of increased natural ventilation. The temperature differences along the tunnel are reduced, reflecting a homogenization and mixing of the air.

There is a constant flow of outside air through the tunnel floor, mixing with the air inside the cave, which is removed by the tunnel roof and the ventilation chimney. Thus, the temperature differences between the tunnel roof, the center of the cave and chimney ventilation are usually below 2 °C (Fig. 2).

A stratification of air flows is produced, with similar temperatures at all points in the same height of the tunnel (Fig. 3), as cold air inlet recorded higher oscillations and higher stratification in the cave. This effect has been more pronounced in the proximity of the tunnel.

The ventilation flow is sufficient to modify the temperature and relative humidity of the cave, recording temperature differences --above 2 ° C-- between certain parts of the cave and the ground temperature, despite the thermal inertia of the ground (Fig. 4.) Due to this behavior, forced ventilation is not necessary in this period.

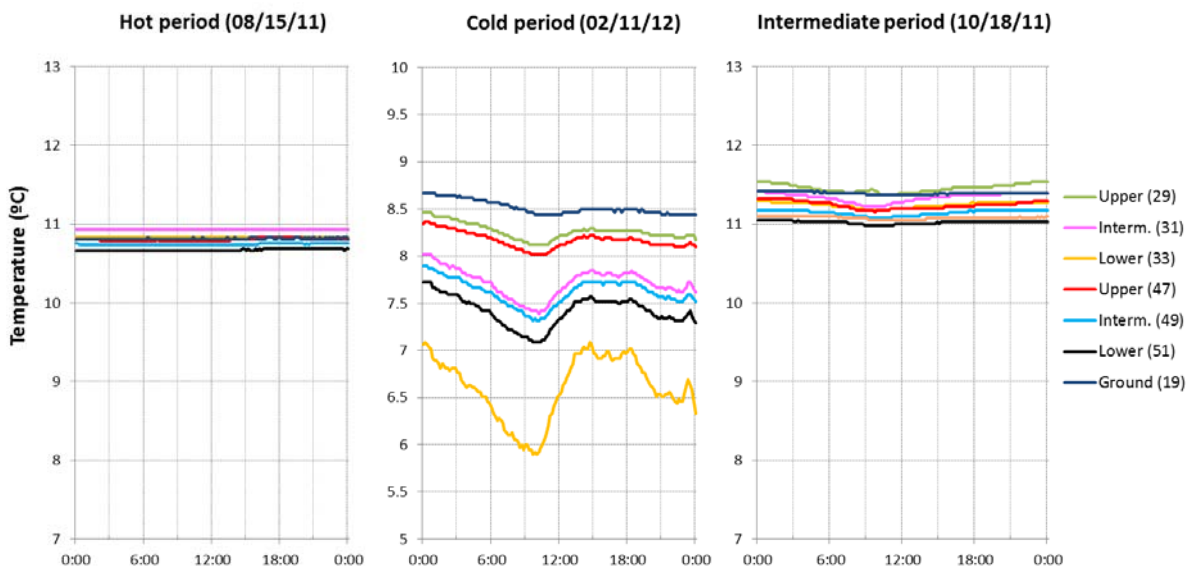


FIGURE 4: Temperature stratification according to the different parts of the cave in representative days during the hot, cold and intermediate periods

### 3.3. Intermediate periods

Intermediate periods --autumn and spring-- show different behaviors based on time of day. During the day when the outside temperature is greater than the inside, the behavior is similar to the summer periods. Ventilation is poor, and the air is stratified in the tunnel and ventilation chimney, influenced by the temperature of adjacent soil, increasing the differences.

At night, when the outdoor and indoor temperature is lower than the air temperature of the tunnel and the ventilation chimney walls, it produces a homogenization of the air in the tunnel, which tends to reach similar temperatures in all of its points (Fig. 3). The ventilation flow is not sufficient to modify the temperature of the cave, registering few temperature differences between the soil and indoor air.

#### 4. Acknowledgements

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#### 5. References

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