

Envelope characterization and self-climatic regulation assessment for a winery in the province of Mendoza, Argentina.

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Abstract

On naturally fermented beverages production, such as high quality wine, the use of auxiliary non-renewable energy for hygro-thermal conditioning of building and barrels, today is almost mandatory. Field research studies on a winery in Argentinas' main wine productive region -the province of Mendoza, famous for the excellent Malbec among other delicate varietals- have been conducted. The winery is situated in the Uco Valley near the Andes Mountains (33°76'SL, 69°03'WL, 1200 m.a.s.l.) with a continental dry-temperate climate with hot summers and cold winters. Daily temperature differences reach 10°C to 18°C. This paper presents results in envelope characterization by amount of exposed surface and materiality and the assessment of its possibilities of self-climatic regulation. A first approach to strategies, as thermal inertia, in order to reach specific indoor temperature requirements for temperature stability for the three main production stages (fermentation, breeding and storage) by using passive architecture are also presented.

Keywords: envelope, thermal inertia, energy flux, hygro-thermal conditions, wineries.

1. Introduction

Wine production consists of different stages that go from grape harvesting until its bottling and client distribution. This process has evolved significantly since its known beginnings in middle east, where there are manuscripts that relate wine existence in 5000 b.C. For a long time, wine production was made in a routinely way, been the case that from excellent quality grapes it could be obtained a poor to a prime wine. Wine was drunk within the year of harvest; and when the new vintage approached, the price of the “old” wine decreased.

In 1714, a Parisian merchant demanded to its Burdeos colleague “good wine: high quality, old, black and velvety.” Naturally it was already known how to breed and ameliorate the wine. It was beginning the quality wine’s era. To Alfonso Herrera, in its work “General Agriculture” edited on the 16th century: ... every winery, to be a good one, must be profound, cold, dry, dark, with thick walls and a good roof... [1] At the time, usually it was recommended that constructions were subterranean to avoid alterations in the alcoholic compounds of wine with high temperatures.

In Mendoza, Argentina, first wineries were documented in the year 1600, buildings were simple and almost without measures of protection and conservation of grape fruits. Small and middle size spaces on the ground. It is supposed that grape juices exposed to temperatures over 25°C corrupted rapidly. Mendoza’s wines were of poor quality and easy alteration of initial properties. [2]

For hundreds years, knowledge on chemical processes and technology used in wine production advanced notoriously. But it is only from the second half of the 20th century that an important evolution on wine elaboration takes place, therefore in 30 to 40 years there was more progress than in all the previous centuries. Fermentation phenomena are precisely known and they can be controlled with modern systems, that most of the time through mechanical conditioning. Nevertheless the energy crises of the '70 –the moment we took conscience of our excessive dependence on conventional non-renewable energies and its associated consequences–, there have not been significant advances related with environmental technologies in wineries dwellings.

Human beings have become an increasingly powerful environmental force over the last 10,000 years. With the advent of agriculture 8,000 years ago, we began to change the land.[3] And with the industrial revolution, we began to affect our atmosphere. The recent increase in the world's population has magnified the effects of our agricultural and economic activities.[4] Along with the specialization of wine production, and with the need of specific and constant microclimatic conditions, wineries buildings became more and more energy-dependant. Industrial sector is one of the most intensive systems that humanity has created. It consumes substantial proportions of natural resources for its construction and operation, and also participates in the disposals to the biosphere. The industry should of been conceived as a energy resources and materials management, as a part of constant fluxes and exchanges of energy and materials within the biosphere cycles.

Interior – exterior exchanges happen through the skin or envelope of the building that separates “interior” from “exterior”. The envelope is a dynamic border that interacts with external natural energies and internal building environment. It is a fertile field to the development of layers and flexible control spaces that would facilitate the adaptation to the changing climatic characteristics.

This paper presents results in envelope characterization of Salentein winery, in Mendoza, Argentina, by amount of exposed surface and materiality and the assessment of their possibilities of self-climatic regulation. A first approach to strategies, feasible to be used on each case studied, in order to reach specific indoor temperature and humidity requirements for the three main production stages (fermentation, breeding and storage) by using passive architecture are also presented.

2. Methodology

2.1 Case study

The winery in study is situated in the Uco Valley in the Province of Mendoza near the Andes Mountains (33°76'SL, 69°03'WL, 1200 m.a.s.l.). It has a continental dry-temperate climate with hot summers and cold winters. Mean daily temperature differences reach 10°C to 18°C. , that result an excellent Malbec grape among other delicate varieties.

The winery was designed for both form and function in the shape of a cross (Figures 1 and 2), allows for customized gentle hadling of the grapes, reducing the distance wine needs to be moved between winemaking steps. Each of the wings is a small winery with two levels –a ground level that houses stainless steel tanks and French wooden vats for fermentation and storage, and an underground level for aging wine in oak casks. The two levels allow wine to flow from the tanks to the barrels by a traditional gravity transfer system. The four wings converge in a circular central chamber which resembles an amphitheatre and was inspired by ancient classical temples. The subterranean stone floor of the cellar is a striking feature. Viewed from the ground level above, the floor of the central chamber reveals an important formal and symbolic design. The design is based on a modern compass whose tips are oriented towards the cardinal points as a means of relating this winery to the rest of the world. (Figure 4). Natural stone from the Cuyo Regions was used, including yellow quartzite sandstone, green chlorited type schist, and red limolite sandstone. [5]



Fig.1 Main East Entrance.

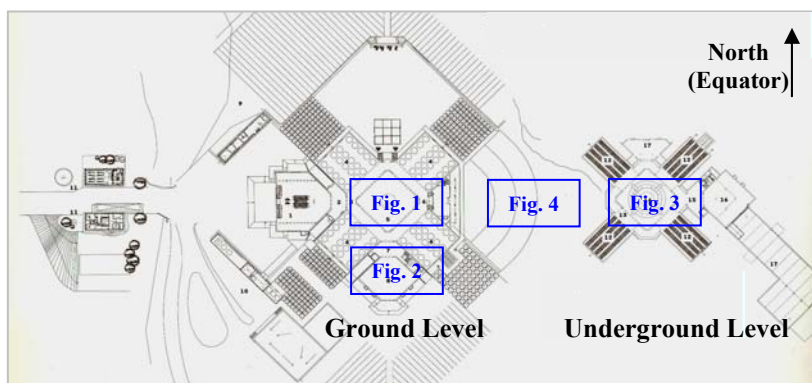


Fig.2 Winery's ground and underground level plans.

There will be compared three spaces within the winery following the three main stages in wine production:

A- Ground level fermentation. (Figure 3)

Wine starts its fermentation process in temperature-controlled stainless steel tanks. Natural light comes from a transparent dome located on the axis intersection of the crossed morphology. Artificial lightning completes the illumination of the space attached to columns and the exposed structure of the roof.

B- Underground level breeding / storage: (Figure 4)

In the underground cellars, wine is aged in small (225 liter) French oak casks with a capacity of 5000 barrals. Subterranean space is naturally maintained at a constant 12°C temperature and 80% humidity. Natural light comes from the ground level through an oculus that connects visually and thermally both levels. Notice that the photograph has been taken with a very sensitive lens for a long time of exposure to enable to “see” within the darkness of the space.

C- Ground level premium breeding / storage (“Primus room”). (Figure 5)

This ground cellar houses 12 temperature-controlled French wooden vats with capacity of 7.600 liters each. Notice in Figure 5 that 10% of the façade is glazed and therefore the room presents higher levels of natural lighting. Also take into account the use of individual artificial illumination of vats and the great contrast of luminances in the interior space.



Fig.3 Fermentation: Groung Level.



Fig.4 Breeding: Underground Level.



Fig.5 Breeding: Ground Level

2.2 Wine climatic needs on each production stage

Optimal environmental conditions on different sites in the wineries, vary according to the needs of workers and the better settings for breeding and keeping wines. Temperature and humidity regimes and the principal environmental factors that need to be precisely controlled in the different sites of wineries. Nevertheless, on some spaces, there have to be taken into account illumination levels to be adequate to work and the total absence of estrange odours; sometimes evacuated with the correct ventilation, and other times controlled by construction materials.[6]

A-Fermentation: on metallic double-skinned tanks.

- Temperature is more important in the containers than in the total dwelling. Between the double skin of the casks where fermentation is performed, tubes are placed, in which hot or cold water circulate depending of what is needed at the time.
- As these casks have a superior opening, CO₂ generated by chemical reactions, that has a higher density than air, descend and accumulates in the inferior part. Therefore inferior ventilation is needed to renovate the air.
- As light can also affect fermentation, therefore it has to be controlled in order to allow workers to perform their tasks attending to the wine production process.

B- Breeding: on wooden (American or French oak) barrels and casks.

In this stage stability within the following reference ranges is very important:

- Air temperature between 12-16 °C and relative humidity between 70-82 %.
- To eliminate bad odours and other air volatile substances that can filtrate through wooden barrels.
- Minimal light. Only when it is absolutely needed.

C-Storage: on glass bottles in cellars.

Of all stages, in this last one inside the building, stability is also a priority. To keep the four microclimatic parameters (temperature, humidity, illumination and ventilation) controlled is essential to obtain the expected result. At this moment the wine is bottled and it will not be moved until it is ready.

- Very low illumination levels are here more important than in previous stages because the wine is bottled on glass that lets the light in, specially on the ultraviolet range of the spectrum, that can affect the most the final quality of the wine.

2.3 Envelope analyses:

In a winery thermal inertia is crucial due to the constant need of stabilized temperatures. A thermal abrupt change can put the whole process in jeopardy. Therefore, the analyses will start with the characterization of the envelope of the winery by amount of exposed envelope and materiality. Then, thermal inertia of the different materials of the envelope will be calculated with Eduardo Torroja Institut Equations (Eq. 1 and 2), and its possibilities of self-regulation from the comparison of the heat flux by using Fouriers Law Equation (Eq. 3). Finally, all these data will enable to relate building performance to the climatic needs in each of the three selected spaces: (A- Ground level Fermentation, B-Underground level breeding and storage and C-Ground level premium breeding and storage (Primus room)).

$$I = R * S_{24} \quad (1)$$

$$S_{24} = 8.48 * 10^{-3} \sqrt{\lambda * \rho * C_p} \quad (2)$$

Where:

I = thermal inertia adimensional parameter

R = thermal resistance (thickness "e" / λ) ($m^2.K/W$)

S_{24} = twenty four hour factor

C_p = specific heat at a constant pressure (J/ kg.K)

ρ = material density (kg/m^3)

λ = thermal conductivity (W/m.K)

$$Q = U * S * (T_e - T_i) \quad (3)$$

Where:

Q = flux (W)

U = heat transmission coefficient ($W/m^2.K$)

S = Envelope surface (m^2)

T_e = Exterior temperature (K)

T_i = Interior temperature (K)

3. Results

3.2 Envelope Characterization

3.2.1 Amount of exposed envelope [7]

The winery presents 70% of the envelope is exposed to the exterior and therefore is located over the surface, and 30 % of the envelope is subterranean. Figure 6 shows an scheme and the section. Also see Figure 2 for the building plan to complete the graphical information of ground and underground dimensions.

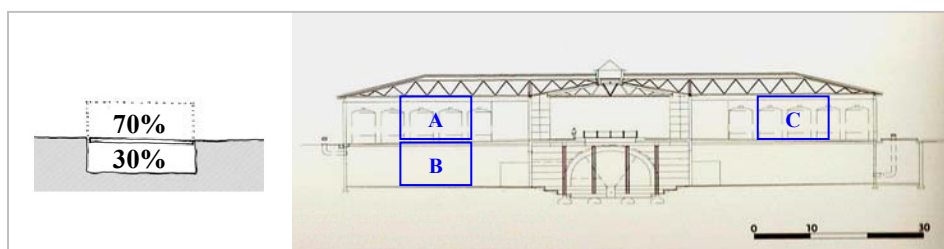


Figure 6: Scheme and section of the winery showing the spaces analyzed on both levels.

3.2.2 Materiality

Table 1 presents a description of the main materials of the envelope classified by level and amount of layers. Heat transmittance or U, that depends of the particular thickness used in the building, is shown to point that materials such as stone and reinforced concrete present different thermal conductivities but equal U values. Also notice that stone and hermetic double glazing that have the same thermal conductivity due to the thickness present extremely different U values.

Table 1. Envelope materials

	Layers	Density (Kg/m ³)	Specific Heat (J/Kg.K)	Thermal Conductivity (W/m.K)	Thickness (m)	U or Heat Transmittance (W/m ² .K)
Underground Level	Earth	1800	1460	2.10	1	2.12
	Stone	2400	800	2.50	0.30	8.33
	Reinforced Concrete	2400	805	1.63	0.20	8.33
Ground Level Single Layer	Hermetic Double Glassing	----	----	2.50	6+6 0.012	208
	Reinforced Concrete	2400	805	1.63	0.20	8.33
Roof Multi-Layer	Zinc	7200	390	110	0.012	5524
	Fibreglass	25	1500	0.04	0.10	0.40
	Ceiling	770	2383	0.44	0.012	3.7

3.2 Self-climatic regulation assessment

Thermal inertia of the different materials that compose the envelope of the building are:

- Earth (1m thickness) = 93.53
- Stone (0.30 m thickness) = 22.20
- Reinforced concrete (0.20 m thickness) = 18

Therefore, it will always be preferable for production stages that require thermal stability, that is breeding and storage (Cases B and C) to have a subterranean space that regulate by its own characteristics the stability in temperature and humidity parameters.

To calculate energy fluxes for the three studied spaces and compare their possibilities self-climatic regulation by reducing the amount of watts exchanged between interior and exterior, there will be established two fixed parameters:

$$S = \text{Envelope surface} = 100 \text{ m}^2$$

$$\Delta T (T_e - T_i) = 10 \text{ K}$$

The following results were obtained. They show a tendency of the amount of energy flux that will be exchanged in a fixed circumstance.:

- A – Ground level fermentation: Q = 8330 W
- B – Underground level breeding / storage: Q = 2120 W
- C – Ground level premium breeding / storage: Q = 19164 W

4. Discussion

The envelope influences greatly how the interior spaces will behave naturally. If we take into account that: 1) DD (base 16°C) are near 2000 in the Uco Valley, 2) mean exterior temperatures for summer are 29.7°C, 3) differences between the optimal interior temperature and the exterior temperature can reach 14°C to 18°C in summer; in order to produce wine without the use of auxiliary cooling, will be highly recommended to have a good thermal inertia that will maintain stable temperatures in the desired ranges and prevent the use of auxiliary cooling devices. A traditional passive strategy is the use of underground cellars.

In the analyzed winery, Case A (fermentation) is located on the ground level. Its temperature requirements (under 20°C) are more flexible than for cases B and C. Nevertheless stainless steel tanks have incorporated an interior temperature regulation system to regulate the temperature of the fluids. The possibility to accelerate or slow the fermentation process at will by the enologist is also a requirement of this production stage. It is also important to take into account that the displacements of wine fluids during the elaboration process also takes energy and therefore it is a great decision to use gravity to perform most of them. This is why it is important that the fermentation space (A) is located over the breeding and storage space (B/C).

For breeding and storage, temperature requirements are very strict and allow a narrow variation. On this stages enologist do not need to change fluids temperature at will, but thermal stability is crucial, therefore thermal inertia is very important. Even though Cases B and C have the same requirements, they are located on the ground (C) and underground (B). As a result space B functions naturally and space C (Primus room) need auxiliary energy to maintain the wine within the desired micro-climatic characteristics. Even more, space B presents 10% of the envelope glazed increasing notoriously the flux exchanges between interior and exterior and diminishing greatly its possibilities of self-climatic regulation. Therefore, wooden vasks have an interior cooling system similar to the ones used in stainless steel tanks. As a conclusion, Table 2 shows as a conclusion the winery evaluation Check-list.

Table 2. Winery evaluation Check-list

		Temperature (°C)	Humidity (%)	Ventilation	Illumination (lux)
Fermentation	Production requirements	< 20 Can change gradually	60 – 90 Can change gradually	Strong ventilation Placed low	300 – 500 All types of lightning
	Analysed space - A	Ok	Ok	X	Ok
	Production requirements	12 – 16 Constant	78 – 82 Constant	Slow ventilation Placed high	150 – 200 Not fluorescent or UV
Breeding / Storage	Analysed space - B	Ok	Ok	Ok	Ok
	Production requirements	12 – 16 Constant	78 – 82 Constant	Slow ventilation Placed high	150 – 200 Not fluorescent or UV
Breeding / Storage	Analysed space - C	X	X	X	X

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