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World Renewable Energy Congress VI (WREC2000)

Editor: A.A.M. Sayigh

THERMAL STABILITY AND ENERGY EFFICIENCY IN WINE STORAGE SPACES

Ridge Winery, Lytton Springs, Healdsburg, California

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ABSTRACT

The authors were asked to investigate the dynamic thermal performance of a winery building designed by Architects Freebairn-Smith & Crane. The objective was to evaluate the effect of the building fabric (particularly the strawbale wall construction) in moderating the impact of climatic variation on the internal environment in order to assess the need for auxiliary heating or cooling in the different areas of the building to achieve the thermal stability required particularly in the barrel storage room. A comparison is made with a fully serviced reference building.

A dynamic thermal performance program (SERI-RES) was used to construct a five zone thermo-dynamic model of the building. An hourly weather data file for a whole year has been constructed using temperature data for Healdsburg. A base case model was built on information derived from drawings received from the architects. The model was then varied in a series of runs designed to test possible improvements.

KEYWORDS

Building Fabric, Infiltration, Strawbale Construction, Air Tightness, Barrel Room, Thermal Stability, Energy Efficiency.

INTRODUCTION

Wine storage requires a rigorous and well tempered environment where temperature conditions should be kept very stable throughout the year. Traditionally wineries are constructed with heavyweight materials and very often underground structures provide the thermal stability required. In Healdsburg California, the location of the proposed Ridge Winery, heavy construction is limited due to the vulnerability of the soil to seismic activity. The architects were prompted with the dilemma of providing a building skin which is able to limit internal thermal fluctuations and which at the same time is structurally lightweight. Their answer was strawbale, a material locally available and a common constructional technique in the area. Following early discussions with the architects related to the general thermal performance of the proposed building, the authors were asked to investigate its dynamic thermal performance throughout the year. The objective was to evaluate the effect of the building fabric in moderating the impact of climatic variation on the internal environment in order to assess the extent to which mechanical cooling or/and heating will be required in the different spaces. The exercise also enabled us to test the sensitivity of the performance of the building to design changes.

THE BUILDING

The proposed design is an east-west orientated single storey building with a double height production area (Couvier). A mezzanine level accessible from the production area accommodates the offices and administration. The L shaped Barrel room (Chai) is used to store the maturing wine in barrels and the Case Good stores the bottled wine. The Testing Room functions as a reception area. The Crush area is placed outside on the North side, under a canopy in front of the Production area (Figs. 1, 2).

REQUIREMENTS

The most sensitive area is *the* ***barrel room*** where the maximum acceptable temperature is 20°C with 14°C being ideal. Similar temperature conditions are desirable in the ***case goods*** store, however a roll-up or freight door opening directly from outside into the case goods store introduced later in the design, implied that greater variation would be acceptable in this space. The relative humidity in the barrel room should be kept at 75-85%. In the case goods room the RH should be kept at ambient level. In the ***couvier*** CO_2 can build up during the night hours due to the fermentation process and represent a potential hazard. A means of 'flushing out' CO_2 is therefore required, including low level vents along the north wall and clerestory openings. Heat gains from occupants and lighting were accounted for but gains from the fermenters to the room will be prevented by the water-filled thermal jackets used to insulate the tanks. These jackets are served by an evaporative cooler and will help maintain temperatures in the vessels at 29°C.

The number of visitors to the ***tasting room*** is anticipated to vary significantly through the year but the largest number of visitors is excepted during midseason reaching the minimum during the hottest part of the summer. The peak acceptable temperature in the tasting room is 27°C, while the minimum acceptable in winter is 18°C. The same temperature criteria apply to the ***offices*** and ***laboratory*** areas.

ENVIRONMENTAL DESIGN STRATEGY

The proposed building envelope is treated as a lightweight assembly (as opposed to high mass or heavyweight construction) using strawbale for the construction of the walls (R value for walls and roof very similar at approx. 43) and a lightweight insulated roof. Provided air infiltration rates can be minimised by an air tight construction then stable internal temperatures should be achievable. However, low infiltration rates must be *designed* for and *managed*. For the designer this implies that emphasis should be placed on achieving 'tight' construction details. For the manager this implies that access to sensitive areas should be strictly controlled, particularly during extreme weather conditions. In the barrel storage and case goods areas the wine itself will provide significant thermal storage capacity, and this will help to stabilise internal temperatures. Elsewhere in the building, the combination of high 'R' values and avoidance of solar heat gains and the use of night cooling will help to moderate external temperatures.

THERMAL MODELLING

The thermal performance of the building was investigated through a series of computer based dynamic simulations where the internal air temperature of each zone was predicted every hour for a full year. The thermal model used was SERI-RES developed for the US Solar Energy Research Institute (SERI). The program allows very accurate treatment of the thermal effects of solar energy through the building fabric, and enables a detailed study of the effect of materials and constructional components on performance.

The geometry, orientation and constructional configuration of the building was defined in the program based on the drawings supplied by Freebairn-Smith & Crane Architects. The Base Case was configured as four zones (combining Barrel Storage and Case goods as a single zone). This was modified to five zones (separating the case goods area) for all subsequent runs. The five zones are: 1 Tasting Room, 2 Offices, 3 Couvier, 4 Chai – Barrel Storage 5 Case Goods and Bottle Storage An hourly weather data file for a whole year was constructed using temperature data for Healdsburg (Latitude 38°37' N).

PARAMETRIC SIMULATIONS

The 'Base Case' model (run 1) was built on the assumptions embodied in the drawings received from FS&C. This was a four zone model which treated the case goods area and barrel storage room as a single zone (see Fig. 1).

Run 2 modelled the case goods area as a separate zone, and included an extension of the roof overhang to the south side (to improve shading to the tasting room), removal of east/west facing glazing to the couvier and the provision of internal blinds to windows to the offices. A total of 2368 barrels (50 gallons each) and 3248 cases (12 bottles per case) were assumed.

Run 3 simulated the effects of promoting passive night ventilation to cool the interior of the couvier, offices and the tasting room.

Run 4 tested the sensitivity of the barrel storage area to higher infiltration rates (earlier runs assumed a tight construction with 0.3 air changes per hour).

Run 5 examined the effect of reducing the wine content of the barrels to 25% of that previously assumed. Also, 2 layers of plasterboard were added to the soffit of the ceiling in the tasting room and offices, to increase the thermal capacitance of these spaces.

Run 6 represents the Harvest. the timing of the harvest varies from year to year. We have assumed that the doors to the Couvier are open during the daytime during the harvest which is assumed to last for the whole of September.

RESULTS

The results are summarised in the charts shown in Figs. 3 ,4, 5, 6 & 7. The thermal conditions in the barrel room over the year is shown in Fig 3. Because the most sensitive area to variations of temperature is the barrel room and for the sake of clarity we only show data for this space. This chart is based on the results of run 3 where the most stable temperatures where achieved. The energy analysis charts compare the performance of the proposed building against the reference building and data is shown for the various spaces. Figures for the reference building were provided by the client.

CONCLUSIONS

In this lightweight well insulated building, the main factors which influence the temperature regime are shading to glazing, background infiltration rate, night ventilation in summer, and the thermal capacitance of the stored wine. Conclusions for each zone can be summarised as follows:

The Tasting Room: The Tasting Room as modelled in run 5 shows a significant improvement over the Base Case. The combination of shading, night ventilation and internal thermal mass (wine bottles plus two layers of plasterboard to the ceiling), have the effect of reducing the number of hours above 27°C from 1300 to just 26 over the year. We believe that this is probably acceptable, and that if these measures can be implemented then mechanical cooling will not be required.

The Offices: Successive improvements to the offices again have a dramatic impact on performance. However, in spite of these improvements the number of hours above the 27°C threshold is still over 90 per year. Provided the staff have control over ventilation of the office spaces then we believe that these conditions will probably be acceptable, but the client must decide whether to proceed on this basis and see how staff respond in the first summer, or install mechanical cooling to bring down peak temperatures for these 90 hours from the outset.

Couvier: The effect of night ventilation, which could also help with dissipating any CO_2 build up, has quite a dramatic effect, reducing the number of hours above 21°C from over 1500 in run 2 to just over 500 in run 3. Runs 4 and 5 have a negligible effect on the Couvier, but the harvest period (run 6) during which the doors are left open during the day, has a substantial effect, creating a temperature regime in the Couvier which follows a few degrees below ambient. An estimate of the range of likely ventilation rates during the harvest could be derived from CFD analysis. This could look at day and night time scenarios, and could also be used to predict residual CO_2 concentrations within the couvier, and the viability of using natural ventilation to flush out CO_2 during the fermentation period. With motorised dampers to vents at low and high level, which are actuated by both CO_2 and temperature sensors, a system based on natural ventilation could be viable.

Chai – Barrel Storage: The base case result for the barrel storage areas indicates that the building as configured is successful in maintaining stable air temperatures throughout the year. Our base case assumption of 0.3 air changes/hour as a background infiltration rate should be achievable provided 'tight' details at all junctions can be ensured. The temperature regime in the barrel storage area is sensitive to the quantity of wine. Reduction of the wine volume to 25% of that assumed in run 2, has the effect of raising temperatures in the store (700 hours above 20°C). It may be worth considering storing water as well as wine in the barrel room in order to maintain a more stable temperature profile in the first few years before the quantity of wine reaches its capacity.

Case Goods: Temperatures follow the same profile as in the barrel storage zone but are elevated by several degrees. Run 2 indicates over 80 hours above 21°C. When surrounding spaces are night ventilated the number of hours above 21°C drops to 30. This would rise during the harvest but not dramatically. This area will be sensitive to the volume of bottles stored, and it would be beneficial to add two layers of plasterboard to the ceiling soffit, as proposed for the tasting room and offices.

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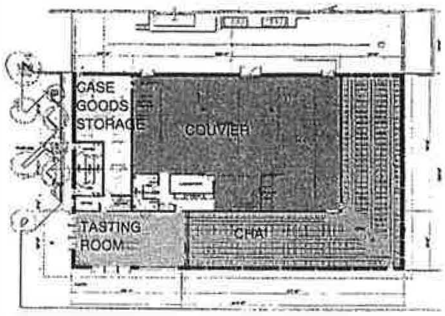

Fig. 1 - Plan (indicating modelled zones)

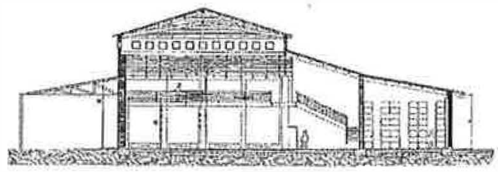

Fig. 2 - Section

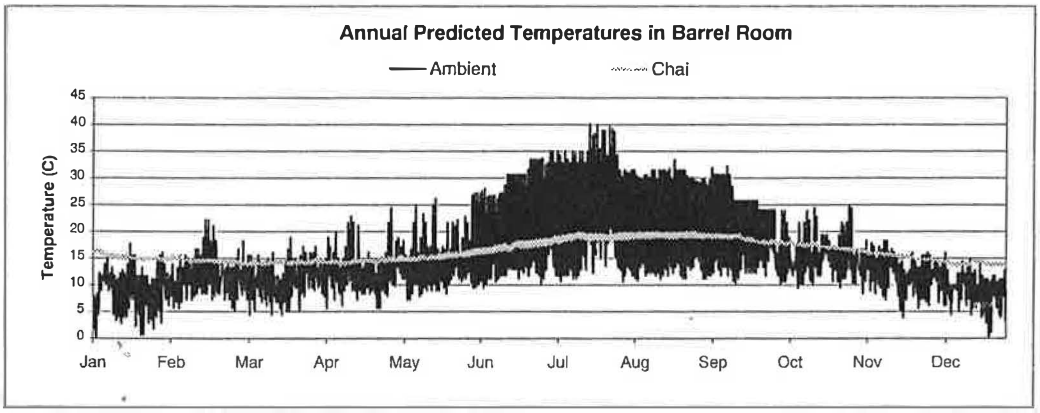

Fig. 3 - Annual Predicted Temperatures in Barrel Room

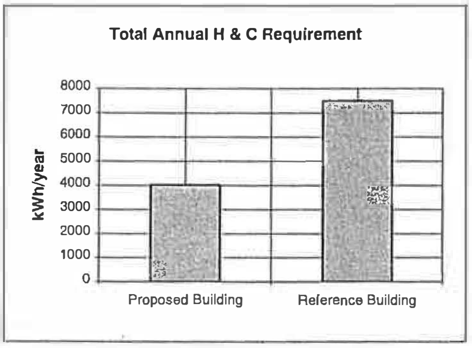

Fig. 4 - Total Annual H & C Requirement

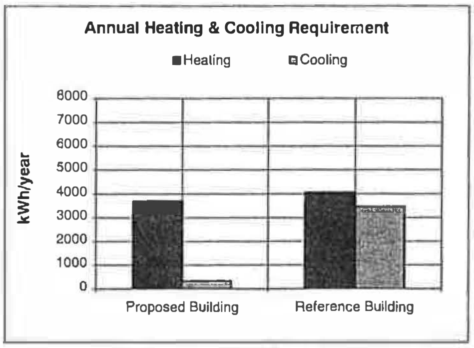

Fig. 5 - Annual H & C Requirement

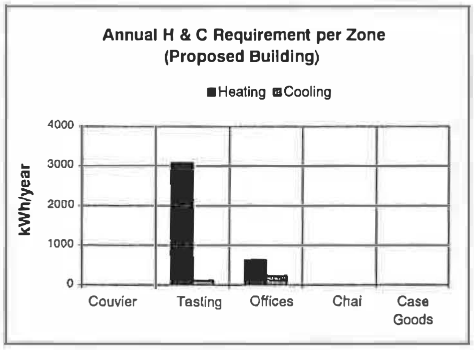

Fig. 6 - Annual H & C Requirement per Zone (Proposed)

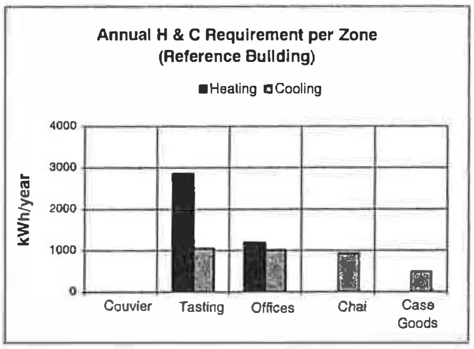

Fig. 7 - Annual H & C Requirement per Zone (Reference)