Multi Media Building – A Case Study - UACH

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ABSTRACT: This paper compares 3 cases; the predicted results of the design of the Multi-Media Building at the Universidad Austral de Chile (UACH), the forecasted results of the what was actually constructed and the predicted results of the building had it been designed to conform to the proposed new building regulations in Chile. The energy consumption of the 3 cases is estimated. The results show that the actual construction and one built to the proposed new regulations building would consume around double the amount of energy as the intended design. It is noted that difference in energy consumption due to infiltration and thermal bridging is the same order of magnitude as that of the difference in transmission losses. The authors propose that these losses are a direct consequence of not following effective details avoiding thermal bridging and poor air tightness and that standard details for considering this should be drawn up for conventional Chilean building methods and materials to supplement the new regulations.

Conference Topic: Traditional Solutions in a Sustainable Perspective
Keywords: energy, efficiency, regulations

INTRODUCTION

The new Multi-Media building (Figure 1), at UACH, is an example of the continuing efforts to include energy efficiency, passive design and good indoor climatic conditions in the new buildings being constructed on the campus with the involvement of the School of Architecture. Basic bioclimatic principles of orientation, solar spaces, buffer zones, exterior insulation, nighttime cooling, etc have been incorporated in the design, still using conventional construction methods. Experience gained from a previous building on campus showed that more attention to the details (insulation, infiltration, thermal bridges) was necessary for the passive principles to be of any use [1]. However, these details have not been followed in the construction and the reasons and predicted results are discussed in this paper.

A normal building in one country could be considered a low energy building in another. The current insulation requirements within the Chilean building regulations are presently being reviewed. In the past only a certain thickness of roof insulation was required, varying according to region, with no consideration for wall insulation, thermal bridges, condensation or indoor comfort. This has lead to ignorance within the construction industry on all sides as to good practice in these areas with building owners bearing the additional energy costs. This ignorance is one of the stumbling blocks when there are attempts to implement effective details and construction. This needs to be overcome for the future regulations to be effective when implementing them.

Figure 1: View of the Multi-Media Building from the South

2. THE BUILDING

2.1 The Building Design

The new Multi-Media Building at the Universidad de Austral, Chile, will house lecture halls and offices with equipment that will allow interactive lectures and laboratories with other universities, via the Internet. International guest lecturers and visitors are expected to visit the building regularly. Part of the design brief was to provide a thermally comfortable environment with low energy and maintenance costs all within a reasonable budget, using conventional materials and locally available products.

Figure 2 shows a typical floor plan of the building, with 2 Auditoriums per floor sharing a control room. To the north there is a circulation space enclosed in glass (Figure 4) that acts as a buffer zone for the hot summer sun and a solar space to capture the sun heat in winter.

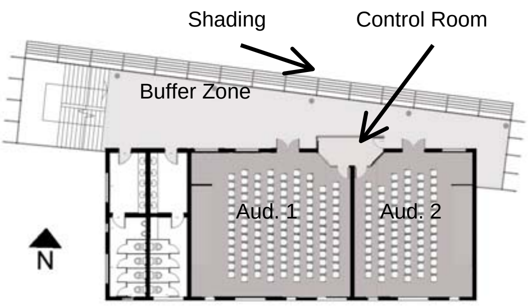


Figure 2: Plan of Multi-Media Building

Due to the concentration of students in the rooms, the noisy street with constant bus traffic in the south and the sensitive nature of the recording equipment in the classes, a mechanical air supply system is installed in lieu of a natural ventilation concept. For the same reason a fully passive design for heating was not possible and so a radiator system was included with heat supply by an oil boiler which is the norm for buildings this size in this part of Chile.

The need for air conditioning equipment during the short summer period was designed out using nighttime cooling of thermal mass, minimal and recessed windows in the east and west facades and solar shading with a ventilated buffer circulation space in the north. The passive concept for the daytime is shown in Figure 3. This paper will not go into any further detail of the passive design and technical systems aspects as they do not fall into the scope and are considered to be the same for all the cases considered in this paper.

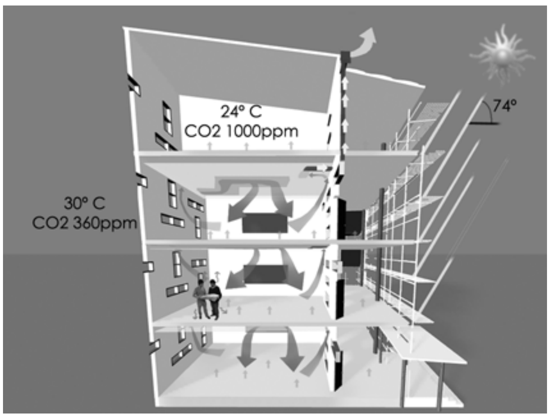
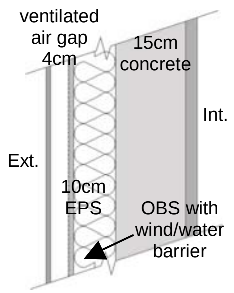
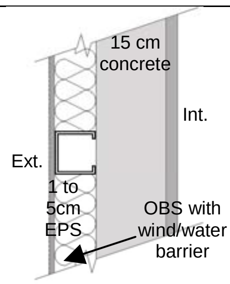
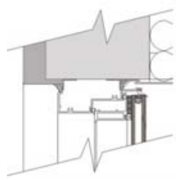


Figure 3: 3D layout showing summer mode

As mentioned in the introduction, the focus of the design was on providing effective details for critical elements of the building that would have a major impact on the energy consumption of the building. Again, as mentioned in the introduction, past experience showed that reduced energy use through passive design concepts would not be effective if the construction did not follow the intended details.

The following elements fell under the scrutiny of the design team; wall construction of the south, east and west facades – insulation and thermal bridging, window details – focusing on reducing infiltration with sealing of the interface between the frame and the wall, and sufficient insulation in a ventilated ceiling space in the roof. These façade and window details are set out in Table 1.

Table 1: Comparison of design details and what was actually built.

	Design	Built
South facing façade	 Secondary structure, galvanized steel profiles: vertical in plane of air gap, horizontal in plane of EPS, thermal bridge restricted to where profiles meet, 8cm x 8cm for every junction, <1% of wall area.	Similar make up to design except insulation thickness varies from 1 to 10cm to cover poor tolerance of caste concrete wall. EPS insulation poorly installed with many gaps between sheets.
East/ west façade	Same as south façade, except with 5cm EPS insulation. (East and west walls adjacent to unheated ablution facilities and sound insulted wall of auditorium.	 No air gap, secondary structure, galvanized steel profiles: vertical and horizontal in plane of EPS, thermal bridge width of profile x total length of profile length.
Windows	Double glazing, low u-value frames, airtight weather-strip (k=1), frame installed over high tolerance plaster and concrete finish for effective sealing. 	Double glazing, simple aluminium frames, weather-strip (k=2). Low tolerance concrete and plaster finish resulting in uneven thickness of the space between the frame and concrete. Impossible to seal in some sections.

The wall construction of the south, east and west facades consists of, from inside to out; interior wall finish (plaster), poured reinforced concrete wall structure, painted vapour barrier, external insulation with expanded polystyrene (EPS), wind/water barrier, ventilated air gap and external cladding (fibrous cement sheeting.) The secondary structure (galvanized steel profiles) holding up the cladding and assisting in the retention of the EPS was detailed for minimal thermal bridging. The vertical spans were in the plane of the ventilated air gap allowing upward airflow. The horizontal spans were in the plane of the EPS sheeting reducing the thermal bridge to the area of where the two spans met (8cm x 8cm). The airflow between the external cladding and the wind and moisture barrier allows for reduced summer heat loads and prevention of water build up and resulting damp in winter.

Figure 4: North façade and view of building from northeast

The roof was detailed with a conventional ventilated ceiling space with mineral wool covering the ceiling boards and structure holding up the ceiling.

Window details minimised expected infiltration between the frame and the wall structure and also for noise and water penetration reasons. A low U-Value aluminium frame with a proper weather strip and good seal was selected and a high tolerance for the plastering and concrete in the window recess specified to reduce infiltration. This was important as the mechanical ventilation system worked using only an extract fan for each auditorium creating a negative pressure to induce fresh air though the sound insulated and acoustically dampened supply ducting.

2.2 The Actual Construction

The details mentioned above where not followed by the contractor. It is not convention in Chile for Architects to provide full construction details. This is left up to the builder who is often unequipped or uninformed as to the design teams intention with regards to energy consumption and thermal performance. In this case the builder carried on as normal, using in-house details and alternative window and insulations specifications that gave a perceived capital saving without understanding the consequences on the performance of the building.

Table 1 illustrates the differences in the building contractor's installation to what was specified.

Wall construction: The insulation thickness varied from 1cm up to the specified insulation thickness (10cm on the south façade, 5cm on the east and west façade) to compensate for the low tolerance of the wall thickness, diminishing the U-value considerably. On the east and west facades the secondary structure was fixed directly onto the wall structure in both the horizontal and vertical spans in the same plane resulting in an effective thermal bridge considerable larger in area to that in the design. No ventilated air gap was left between the wind/water barrier and external cladding.

Windows: The builder selected a cheaper aluminium frame with a lower frame u-value and poorer weather strip. The concrete, plastering and sealing of the frame into the window recess was not preformed as per specification and detail resulting in no seal in many places.

Roof construction: The insulation the builder laid in the roof void was half as thick as specified resulting in a lower roof u-value.

3. THE NEW BUILDING REGULATIONS

The new building regulations have been drawn up in a long process with many different partners involved. The intention is to make the regulations law in 2005. The regulations break down Chile into 7 climatic zones, specifying a minimum insulation values for walls and roofs for each zone as well as maximum window area for each façade depending on the type of glazing used.

Table 2: Proposed new Chilean insulation regulations [2]

Windows
(Maximum percentage of windows related to total vertical envelope)

Zone	Simple glass	Double Glass	
		$3.6W/m^2K \geq U > 2.4W/m^2K$ (*)	$U \leq 2.4W/m^2K$
1	50	60	80
2	40	60	80
3	25	60	80
4	21	60	80
5	18	51	80
6	14	37	55
7	12	28	37

Zone	Roof		Ventilated floor	
	U W/m2K	Rt m2K/W	U W/m2K	Rt m2K/W
1	0,84	1,19	3,60	0,28
2	0,60	1,66	0,87	1,15
3	0,47	2,13	0,70	1,43
4	0,38	2,60	0,60	1,67
5	0,33	3,07	0,50	2,00
6	0,28	3,54	0,39	2,56
7	0,25	4,01	0,32	3,13

Walls

Zone	Option "A"		Option "B"	
	U W/m2K	Rt m2K/W	U W/m2K	Rt m2K/W
1	4,3	0,23	4,0	0,25
2	3,1	0,33	1,8	0,56
3	2,1	0,48	1,5	0,67
4	1,9	0,53	1,3	0,77
5	1,8	0,63	1,1	0,91
6	1,3	0,83	1,1	0,91
7	0,8	1,25	0,6	1,67

Table 2 sets out these new regulations. It is under discussion at the moment whether Option "A" or

Option "B" for the specified wall U-value is followed. Option "B" is more stringent and would result in new houses in the Santiago region requiring insulation adding considerable capital cost in comparison to the existing buildings, which do not have insulation. Option "A" could be met in Santiago without insulation. For the basis of this case study the more conservative Option "B" was chosen for the energy consumption details. The Multi-media building falls within zone 5.

The new building regulations do not take into consideration thermal bridging and air tightness.

4. COMPARISON OF ESTIMATED ENERGY CONSUMPTION

4.1 The Energy Consumption Estimation

The energy consumption was estimated for the following three cases: (a) Building as designed, (b) building as built, (c) hypothetical building strictly according to the proposed new building regulations but with the same details as in (b) which is considered normal building practice in this region. There is nothing in the proposed new building regulations that would force the builder to alter his/her current details and selection of window frames etc.

The resulting u-values of the various wall and roof constructions of the different cases looked at, were calculated using the equation [3]:

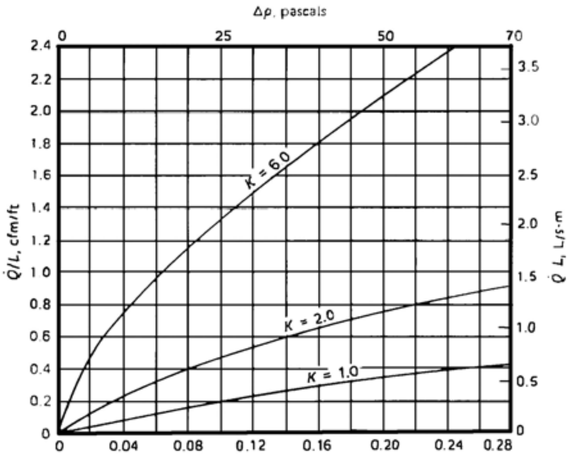
$$U = \frac{1}{\frac{1}{hi} + \Sigma R_j + \frac{1}{he}}$$

Where "hi" is the internal heat transfer coefficient and given the value of 10 for all cases and "he" is the external heat transfer coefficient and is given the value of 20 for all cases. R is the resistance value in m^2K/w of the various materials making up the construction. The results of this calculation are tabulated in Table 3.

The thermal bridges were calculated using the same equation as the u-value of the walls. This simpler method was used as the bridges were quite large in nature and the energy loss due to this was of interest and not condensation issues. (Of course this was also considered by the design team but falls outside of the scope of this paper) Due to the small area of the thermal bridges in case (a) this was calculated into the over wall u value for this case. Separate u-values with corresponding areas were used for the thermal bridges and wall construction in the other 2 cases.

The differences in roof construction resulted in a simple difference in overall u-value between the 3 cases considered.

A method [4] of quantifying the infiltration rate through measuring the crack length of any envelope penetrations (395m for all cases) and multiplying that by a figure read off from the graph in figure 5.was used. The mechanical extraction system was designed to create a 50Pa pressure difference between the inside and outside of the building to draw air in through the duct path. The result of multiplying the crack length by the airflow per metre length resulted in an infiltration rate of approximately double that of case (a) for cases (b) and (c). The accuracy of this method is discussed later on in this paper.



	Wood double-hung (locked)	Other types
Tight-fitting window K = 1.0	Weather-stripped, average gap (1/32 inch crack)	Wood casement and jamming windows; weather-stripped Metal casement windows; weather-stripped
Average fitting window K = 2.0	Non-weather-stripped average gap (1/32 inch crack) Weather-stripped large gap (3/32 inch crack)	All typed of vertical and horizontal sliding windows; weather-stripped. Note: if average gap this could be tight fitting window. Metal casement windows, non-weather-stripped. Note: if large gap, this could be a loose-fitting window
Loose fitting window K = 6.0	Non-weather-stripped large gap (3/32 inch crack)	Vertical and horizontal sliding windows, non-weather-stripped

Figure 5: Figure showing infiltration rate at litres/m crack length relative to an assigned k value of the crack.

Table 3 shows the results of these calculations and these values in turn were inserted into a excel program developed for estimating energy consumption and temperature levels in buildings in the area and used to calculate the results of another case study submitted to PLEA2003 [1]. Table 4 shows the results from this excel spreadsheet.

Table 3: Values entered into program for the different cases

U-values (w/m²K)	(a) New design	(b) As built	(c) New regulations
South	0.37	0.82	1.1
West/East	0.68	1.37	1.1
North	0.68	1.37	1.1
Roof	0.24	0.47	0.33
Ground floor	0.69	4.7	4.7
Windows	2.2	2.7	2.7
Frames	2.5	5.2	5.2
Infiltration ACH/h	0.5	1	1

Table 4: Results from energy consumption estimates

KWhr/year	(a) New design	(b) As built	(c) New regulations
Heat losses:			
Transmission	37447	95619	91872
Ventilation	76800	76800	76800
Infiltration	19200	38400	38400
Thermal Bridges	0	12200	12200
Gains	42000	42000	42000
Total Cosumption	**91447**	**181019**	**177272**
Annual Cost US$	**2743.4**	**5430.6**	**5318.1**

4.2 Outline Of The Results Of The Energy Consumption Estimation

As expected the results of the estimate show that the built building ,case (b) should consume considerably more energy that the intended design. Case (c), considering the proposed new Chilean regulations, appears to be marginally better than Case (b) the actual building. Energy loss through thermal bridges and infiltration appear to be in the same order as the transmission losses when comparing Cases (b) and (c) to (a).

The accuracy of the method used to estimate the energy consumption, requires commentary at this stage. Even if the accuracy of the methods were out by up to, say, 20% there would still be a considerable difference in energy consumption. The purpose of this paper is **not** to provide a value that can in turn be used to consider what additional capital costs incurred through more stringent construction and adherence to specification, but to show the order of magnitude of the differences between the cases and what are the main contributors to these differences. For this the authors propose that the methodology followed to estimate the energy consumption of the different cases is of sufficient accuracy.

It would be difficult to determine more accurately the differences in energy consumption due to infiltration without constructing another building as per the intended design and conducting pressure test, which in this project would not be economically viable. Considering this the results of case (b) and (c) should be seen as to be very similar.

6. CONCLUSIONS AND RECOMMENDATIONS

The proposed new Chilean regulations are a step forward to realising more energy efficient buildings through making it law to provide better insulation. The results from the energy consumption estimates laid out in this paper show that the energy loss due to infiltration and thermal bridges are in a similar order to that of the difference between a well insulated and constructed building and one using the conventional methods in Chile. Infiltration and thermal bridging is directly related to effective detailing of facades and envelope penetrations and good construction practise. Constructing an envelope with the same u-value as prescribed in the but using details similar to that is in the proposed design detailed in this paper would result in considerable energy savings. This would not involve the use of any materials not used in the Chilean building industry and would result using traditional building materials used in a sustainable way.

With this in mind the authors recommend that standard details for wall constructions and penetrations of envelopes avoiding thermal bridging and poor air tightness be drawn up for the various construction methods and materials that are the norm in Chile. These standards details should then supplement the proposed new building regulations and be distributed to the professionals involved on both the design and construction side. Should any deviation from these details be necessary then it should be up to the design team or the builder to prove to the authorities that the deviations would not result in additional energy consumption.

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