Design snap shot 18: Vaulted Ceilings

Summary

Introduction

This snap shot discusses the wavy roof designed for Council House Two (CH2). It outlines how this was integrated into the design, the costs and benefits and the final outcome.

Figure 1. Mock up of the ceiling testing how differing elements will fit together

Drivers and objectives

The ceiling has to perform a range of differing tasks from absorbing the incidental heat gains from the office, to bouncing light as far into the space as possible.

Being such an important part of the building this item has to be right. Modelling, mock ups and other devices were used to tune the design.

Costs and benefits

The concrete ceiling is unfinished, to optimise the thermal mass performance, and is designed as a component of the structural floor system. The high quality of the pre-cast finish means there is no requirement for a false ceiling system, which offsets the costs. The concrete itself provides a thermal mass for radiant cooling, and the curved profile provides a zone in which heat build-up can occur.

The ceiling forms a vital part of the energy efficiency strategy of the building, and its ecological footprint is further reduced by the recycled constituents of its concrete mix.

The development of the precast form is complex and requires precision. This, in part, is offset by the savings of using a precast system by reducing installation time.

Outcomes

The concrete itself provides a radiant thermal mass for cooling, and a zone in which heat build-up can occur without a reduction in the comfort level of the occupants. The thermal mass is cooled at night through the use of night purge.

The curved roof provides fixing positions for chilled ceilings and lighting and service conduits in the design. Light bounces off the vaulted ceilings, deep into the office, reducing artificial lighting needs.

Figure 2. A computer model testing the feel and effectiveness of the wave form

Lessons

Several disciplines in the design team had to work together to integrate the structural, thermal, acoustic and service requirements of the ceiling system.

The design charrette process created a collaborative solution-seeking environment (see Snap Shot 3: The Design Charrette). When the quantity surveyor did not have a standard cost for the precast units, he was able to work with the structural engineer to get a price from a manufacturer.

The use of precast elements means that quality control can be improved. Unlike a slab poured on-site this was important to ensure everything fitted together when put in place. The high quality cast also ensured a consistent visual appearance of the various elements fitting together.

Snap shot compiled by Dominique Hes, dhes@unimelb.edu.au from input by the entire design and construction team.

Figure 3. Precast panel

More detail

The vaulted 'wavy' ceilings are made from precast concrete. They help the building spaces to remain cooler during the day as the thermal mass absorbs some of the excess heat, which is then released during night purging.

The 'deep space' office building presented many challenges to the designers and engineers for lighting and air conditioning, particularly given the objectives of low energy use and high indoor environmental quality. The solution is a unique system of air and light distribution: barrel vaults running in north to south direction like waves along the ceiling. This provides space for air exhausting as well as enabling light to penetrate deep into the offices.

Concrete mix and precasting the ceiling system

Each ceiling module is cast within a fully enclosed steel formwork, allowing it to be poured in one go. As the dimension from the top to the bottom of the wave form is 950mm, the viscosity of the concrete mix is of vital importance. If too viscous the concrete will have imperfections, if too sloppy then it may not have enough strength. River aggregate was used to get a light colour, which is good for bouncing light from the façade deep into the plan and which also gave an excellent finish when sand blasted. A plasticiser was used in the mix to improve its flow properties. This also gives the precast forms their white appearance. Fly ash was used to replace a percentage of cement and reclaimed aggregate was also used to reduce the overall embodied energy of the panels.

Figure 4. Pre-cast ceiling system

Prototype space

Prototyping the general office space of CH2, in the office where the Council's CH2 project team works, was a very rewarding initiative. Unlike a computer animation you can see and touch the space, and the elements in it. This gives a much better perspective to discuss issues for the project team, as not everyone has the ability of visualising spaces and understanding them from plans or computer images.

Initial costing of the design

The quantity surveyor did not have a precendent for the costing of this unique system. Initially it was not clear whether precasting was even possible, and there were other associated issues such as cost of transportation, delivery, storage and lifting. Bonacci Group, the structural engineers, took on this challenge and contacted precast concrete manufacturers and within the week had the information required for providing a costed solution. This provided the confidence for the team to decide on this as the flooring/ceiling system.

"I … think they had a section of the precast ceiling panels virtually designed in the first month that we started this project, so there was some really basic decisions set up and agreements that we used to structure the building from day one."

Stephen Webb, Director, DesignInc

Figure 5. Computer model of the office spaces with precast concrete ceiling-floor system

Figure 6. Prototype full scale of the office spaces with precast concrete ceiling-floor system

Figure 7. Prototype full scale of the office spaces raised floor

Challenges for fixing the chilled panels to the vaulted ceilings

The fixing points which hold the chilled ceiling panel to the vaulted ceiling differ due to the way the air and lighting systems were configured.

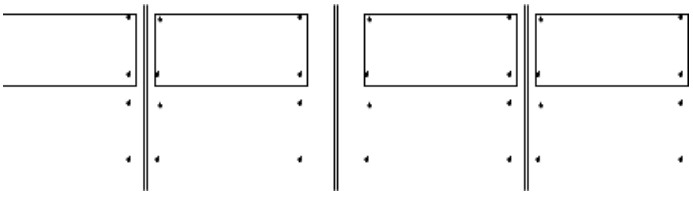

Figure 8. Representation of ceiling and initial proposal for off set fixing points

This added a layer of complexity for the building contractors. Each panel needs to match fixing requirements for the chilled ceiling panels. The sub contractors installing the chilled ceiling panels used the prototype space to look at the vaulted ceilings and chilled ceiling panels. As an example, using the prototype space for looking at the physical problems they came up with a simple solution for the fixing of the chilled panels of the ceilings using a fixing system that could swivel (see Figure 8), this meant all the panels could be made from the same form.

Integrating the chilled panels , beams and wavy roof design

The use of chilled panels is relatively new in Australia. Their use in CH2 was driven by the use of water as the main method for cooling and thermal storage. One interesting aspect of the chilled ceiling panels is their integration with the vaulted ceiling design.

Through experiments conducted, it was found that the best place for the panels was half way up the curve of the ceiling's wave, allowing proximity to occupants, and space for stale air to move above the panel. Many other issues were ironed out in similar fashion with all parties involved working together bringing their experience and expertise to the table to look at the optimum way to make all the systems work together.

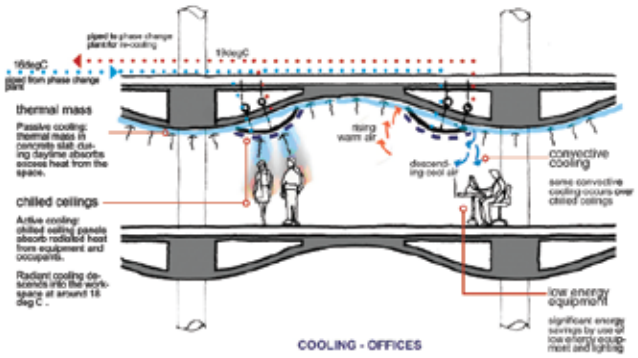

Figure 9. Depiction of how the vaulted ceilings and chilled panels are expected to work (DesignInc)

Acoustics performance

In an open office the hard concrete and metallic surfaces of the ceiling, chilled panels and beams can cause poor and disruptive acoustic performance. To solve this, the acoustic consultants specified treatments to the panels and beam which will help minimise these negative aspects. These treatments, in addition to the use of good quality carpets, will allow the space to perform well acoustically.

Lighting and services

Different lighting systems were tested in the prototype space. Along with their visual performance, the issues of replacement and maintenance of the differing systems was considered. Access space had to provide for an electrician to refit a luminare or a plumber to physically maintain a chilled ceiling panel with a spanner to touch the space and the elements in it. This gives a much better perspective to discuss issues for the project team as not everyone has the ability of visualising spaces and understanding them from plans or computer images.

Figure 10. Trialling different lighting systems