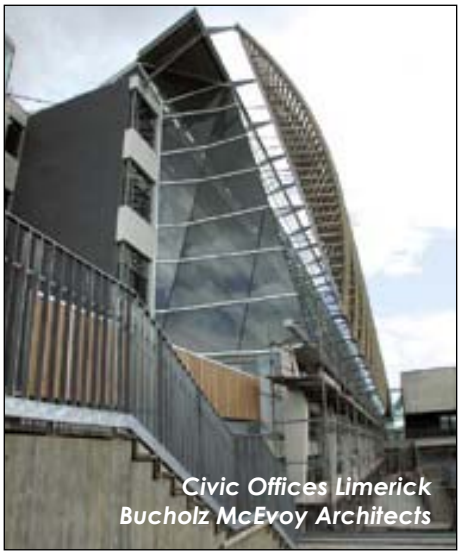
Concrete & Sustainability

Merritt Bucholz Presentation to ERMCO Conference Helsinki

Concrete has been in our work shaped by many factors: light, acoustics, hand craft, texture, structure, thermal physics. As a material that can structurally assume any shape, concrete is able to take on a variety of highly specific functions, within a single form. Its contribution to the environmental performance of a building has many facets - human endeavour, physical properties and formal properties.

Ireland has in recent times experienced something of a revolution, an unprecedented economic boom, which has fuelled the building of everything from roads, bridges and tunnels, to hospitals, schools, housing and civic buildings. A large part of this transformation has been the construction of local authority headquarters buildings: virtually all local authority headquarters in Ireland have been constructed in the last 10 years. The Irish Republic was founded just over 80 years ago - and until recently had virtually no buildings constructed specifically to house local government. These buildings have been awarded through competition generally, and generally the briefs of these buildings contain the strong objectives of creating an open and transparent expression of local government, and a building which fundamentally is in balance with the natural environment. I think this building programme is remarkable, and more so because it has been centrally planned, or administered, but nevertheless, it has happened.

We started our practice when we won the open international competition to design one of these buildings, Fingal County Hall, in Dublin in 1996. The building was completed in 2000, and we started another such building in Limerick for Limerick County Council.



Civic Offices Limerick
Bucholz McEvoy Architects

Fingal County Hall
Bucholz McEvoy Architects

The approach outlined in the brief drawn up for Fingal County Hall by that County's architect David O' Connor, has established a precedent that has been used on subsequent projects throughout Ireland: Fundamentally, an open and transparent expression of local government, which embodies the principals of sustainable building design: an icon of local government which is also an icon of low energy building. For us the building is a place where people work, (and spend much of their lives), the building is a civic building where the public comes to visit the local authority and conduct business, and the building is a political centre, where the politicians meet to debate, in the council chamber, and have their offices. The fact that it is a working environment where people spend most of their lives means that we wanted to create the best possible environment to work in. The fact that it is an icon of local government means that people see it as representing them, and their county. The fact that it is a political centre means that democracy is within this building held sacred. Important in all of these aspects is the relationship that these new ideas have with what already exists, socially, contextually, and environmentally. By paying close attention to these things we are able to tune the building into each specific idea. Paramount in this is the environment. We strongly believe that local government must build responsibly and responsively.

Our work is focusing available building technologies on achieving an environmental result; we tune the building into the environment; that is using to the full extent the building structure and envelope to obtain the best possible internal environment, in balance with nature, consuming less energy in its operation, and looking like it does so. The basic building components are focused on delivering the best possible working environment, but one which consumes the least amount of energy possible in its operation.

To really understand how this process works, we should begin by understanding the climate in Ireland; what are the parameters - Ireland benefits from a very mild climate; annual temperatures vary between highs of just 28°C in the summer and lows of around 0°C in winter. Temperatures fluctuate between 8°C and 18°C; this is normal. Air temperature is not much affected by land as the island is not large, which means that the climate is very coastal, even inland. Ireland is also windy; being a small island located in the upper left hand corner of Europe, we get all of the 'weather' as it comes across the Atlantic and this produces a constant wind speed. It is very rare to have a still day in Ireland, but more frequently we have sun - as clouds are pushed across the island by the wind, the weather changes frequently. My impressionistic description of it would be; the sun comes out for ten minutes, then it disappears, then it comes out again, then it rains, then it is cloudy, then the sun comes out and so on. This means that people living here can never be too sure of what to wear, or what they could do - planning takes on a volatile variable, the weather; it may rain, it may be cold, it may be warm. This also means that contractors, when they are pouring concrete, are more amateur weatherpersons - tuned into the forecast and always with an eye to the clouds so the next concrete-pour isn't ruined by a sudden down-pour. The combination of a mild climate with frequently changing weather means that Ireland is a very good place to build and that people are generally used to changing environmental conditions. There is no need to air condition buildings in Ireland because the internal external environmental relationship is not extreme; the balance between inside and out is already quite

close and quite liveable. People are also accustomed to living closely with the environment, but what exactly is Thermal Comfort? It is defined in the ISO 7730 standard as being "that condition of mind which expresses satisfaction with the thermal environment". A definition most people can agree on, but also a definition which is not easily converted into physical parameters.

In our buildings, we study very closely this relationship between internal environment and external environmental factors - one could argue that the reason for architecture in the first instance is to provide shelter fro the external environment; therefore this relationship is the factor which defines the fabric, the material to create this shelter. Our basic philosophy is to tune the building elements which already exists in any case, the structure and the external envelope, as the primary means by which the internal environment is controlled vis-à-vis external environmental factors.

In the two local authority headquarters buildings, we have the possibility to compare two similar environmental systems and contrast two very different sites. The first building, Fingal County Hall, is located in a village in the North Dublin suburbs. The site was first a manor house, then a public park and is opposite an 11th century castle and round tower. There is on the site a crescent of Holm Oak trees and a particularly fantastic Himalayan Cedar. Our first decision was to preserve these trees and create the building, as precisely what was asked for in the brief; an open and transparent expression of local government.

The Fingal building is essentially composed of an arc of offices which also contains a large atrium, the main entrance to the building, connected to which are three office fingers. The entire building, 11,244m^2, is naturally ventilated, so that

there are no fans, ducts or air handling units of any kind to climate control the office spaces. Instead it is simply naturally ventilated through the principal of cross ventilation. Orientation was of course a key factor; the building is oriented such that each office finger has a South facing elevation and a North facing elevation, while the arc has a West facade and an East facade. The office fingers, and the Arc have an optimal 12.75m wide internal dimension, both in terms of cross ventilation with open plan offices and single sided ventilation with cellular offices. The section through the office finger reveals the environmental strategy. Each element of construction is given multiple tasks, which have influenced their form and construction. The facades are used to

control the flow of external air, the supply of fresh air and the exhaust of waste air from the offices. The facades are also used to control the sun; to minimize heat gain, while maximizing natural daylight.

The concrete slab has 5 principal roles, each of which influenced the design in different ways; the exact slab configuration and profile originates from five primary objectives;

1. Thermal: to act as a thermal battery absorbing heat energy during the day and releasing that energy at night, this is required so that we maximize the surface area of the slab.
2. Ventilation; smoothing air flow across the slab.
3. Lighting; Serving as a lit plane which illuminates the entire office, maximizing daylight.
4. Primary Structure; it supports the building.
5. Acoustic; minimizing acoustic transmission across the surface of the slab.

These objectives were modelled during the design stage, using environmental analysis software. The computer simulation is the tool that shapes the fine tuning of the building to the environment. It was possible to simulate and understand the effect of the design of all of the geometry and thickness of the slab, which is represented as a surface area of concrete per m″; the room width and the floor to ceiling heights are also critical factors for the environmental analysis. In this analysis we discovered that the concrete slab had strong effects; it was a thermal battery which absorbed the heat energy generated during the day, thus reducing the need for cooling in warm external conditions, which gave the effect of making people feel more comfortable. The shape of the slab was modelled in our lighting simulations; the objective was to have as much daylight penetrate the building as possible. The structural innovation of a downstand beam in the centre and an upstand beam to 3.1 at the edges; the profile was higher at the edges than at the middle in order to maximize the amount of glass and therefore natural light. The shape of the slab was also modelled to ensure that the profile inhibited transmission of sound across its surface.

Once created for natural light, we thought it would also be ideal to use as a place for reflecting artificial light; indirect

light is the best condition for working in; no glare, minimizing eye strain, and generally uplifting. We designed a light fitting, together with the concrete slab design, with a reflector that was designed specifically for the concrete slab profile.

The complex shape which resulted for these studies could have been achieved through either a precast or an in-situ concrete solution. Both options were analysed and the in-situ solution was decided upon because of the smaller connections at the column heads and the relative ease with which the upstand/downstand beam could be achieved in-situ. We also considered a thin precast permanent formwork solution. The decision to form the soffits using a GRP mould was arrived at as GRP formwork produces an outstandingly smooth finish. The procurement of GRP moulds was difficult because the industry producing GRP for formwork is relatively small. The main contractor found two producers of GRP for Concrete formwork in the UK (they both used the same carpenter to make the form for the moulds).

Ireland has a very developed in-situ concrete industry. There is in Ireland a sophisticated and knowledgeable cadre of engineers, contractors and skilled workers who are capable of producing outstanding quality of concrete poured in-situ. Working with this industry is critical to the quality of the concrete and in particular the design of the formwork. The most difficult detail to achieve at Fingal was the column/slab connection. The columns out-of-plumb tolerance and the mould tolerance gave us a 10 mm gap around the column head/slab junction to fill. This we did using a very thin piece of polystyrene, lining the base of the mould, backed by foam insulation and sealed with silicone. It worked, most of the time but as we had not really solved the problem with the design of the formwork, it was not until the Limerick project that a solution was developed, working directly with the Concrete contractor.

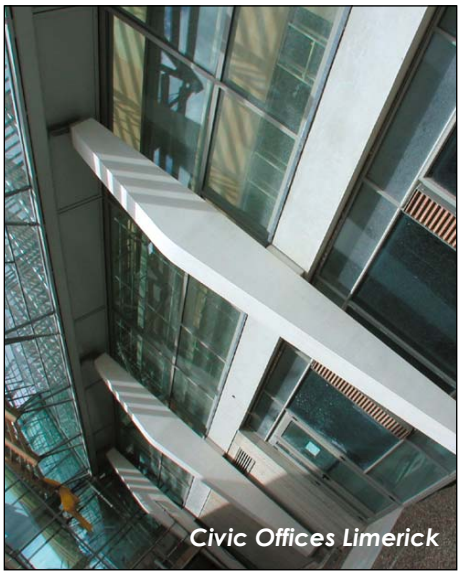
At Limerick County Hall, the solution had to be quite focused on creating a context; the site was very dispersed and offered virtually no context. The design solution for the building came from a desire to construct an environmentally sustainable building, without referring to the constructed context, but referring to the natural one; carefully balanced with the environment, with the clearly expressed intention of showing how that balance was achieved. The site is in a suburb of Limerick city called Dooradoyle; behind the site is space referred to in the development plan as 'semi-natural-open-space' - green space that you cannot get to, cannot be built on, but it is just 'there'. In between the site and the semi-natural open space is a large shopping centre, which grew to become a 'very large shopping centre' during the course of our project. There is a McDonalds, whose presence indicates the economic strength of the area, and there is a sea of parking. The building is simple in plan; a 75 meter long office block, with a council chamber as an object sitting in front of it. Along this 75 meter long block, is the public space of the building; an equally long atrium. This atrium is what we refer to as the lung of the building, driving the ventilation of the building, naturally, cross ventilating from east to west. The section is the key to understanding the environmental and functional approach; a 13 meter wide office block, opens directly onto the atrium. Unlike Fingal, the building is cross ventilated into the atrium form east to west, i.e. unidirectional ventilation. The relatively high wind speeds in Ireland mean that the atrium, despite its orientation, which prefers the south, runs the ventilation by wind effect, not sun effect. The concrete frame is exposed and is profiled to maximize daylight penetration and air flow and disturb acoustic travel across its surface.

The building is constructed from elements, each with a specific function, or a number of highly specific functions. The elements are composed of different materials, but have been designed together, to work together, to achieve an environmental balance. I would like to now take you through a tour of the section's elements, as it is through the performance and construction of each element that we understand how the whole functions.

The Elements

1. Concrete Structural Frame

The deployment of the concrete frame in a direction South West North East means that the building's South side is in the sun most of the day. As the ventilation is driven by wind effect, facing into the prevailing winds was of key importance. The width of the concrete frame is depths narrow (13m) to enable cross ventilation and the column grid is 6 meters along the block and 7.5 and 5.5 meters across the block. The floor to floor dimension is 3.35 meters; we wanted to achieve as tight a floor to floor dimension as possible, while at the same time maximizing the floor to ceiling height, particularly at the perimeter - therefore upstand beams which included the column connections were made at the edges and in the middle a downstand beam of 400mm


Civic Offices Limerick

was cast with pockets, so as to lighten it as much as possible. This enabled us to have a minimum floor to ceiling dimension of 2.7 meters in the centre of the office and 3.1 meters at the edges, while still achieving a floor void of 250mm. The overall effect is of the space lifting at the edges, appearing to be much higher that it actually is - your eye is drawn up along the soffit beams and out to the light. The advantage of the upstand beams was that on the atrium (west) side, it formed the balustrade and on the east side it formed a hanger for the pre-cast concrete light shelves.

The specific geometry, or profile of the slab, was set by modelling the profile for light, air flow and thermal mass, similar to the exercise carried out in the Fingal project; The critical factor in the design being again the maximisation of surface area for thermal mass, the maximization of daylight in the office space, the smooth flow of air across the soffit and acoustic baffeling.

The slab is modular and is intended to simplify and modularise the planning of the office space; to obtain a flexible planning module we utilized a 1.5 meter grid for the ribs which enable one to put partitions where needed (The joints between ribs are designed to accept partitions). All light fittings were mounted to or cast into the slab. This meant the luminaries had to be designed together with the formwork.

Once the geometry was established a Loftings drawing was created from this geometry; in other words the profile, including its 14 meter radiused centre section and all other formed parts were turned into a drawing which a carpenter could work form - a series of distances from a datum.

The carpenter then makes a timber positive of GRP. During this process test moulds are taken to check the details of the

mould. In particular, we were interested in the intersection of planes and the changing radii along the mould and the ends of the mould where the planes all intersected. What we found was that despite the actual and computer models, we had made of the model, there was still much discovered in working with the carpenter. Many subtle adjustments were made to the mould to create as continuous a shape as possible. Once complete, a GRP negative is then made from a Timber positive and finally the GRP positive is made from GRP negative.

Each mould is 1.5 meters wide by just over 5 meters long; they weigh approximately 125Kg each and can be carried by four men. Normally they are

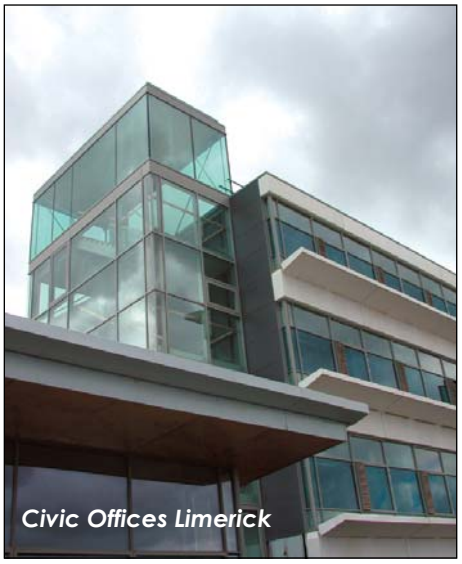
craned up to the deck and placed onto ply table deck. GRP of course deflects quite a lot when a load is placed on it; we therefore had to reinforce the ribbed slab quite a lot to prevent the GRP from faceting between cross supports; plywood ribs were placed at 300 centres. Because the shape of the mould was not flat at the bottom, a triangular shim was placed below the mould to level it - the shim was placed on the flat plywood deck (table tray). The joint between the mould and the flat (plywood) soffit was hidden in the reveal into which the light fitting was fixed. The light fitting, a modified version of that used in Fingal, was again designed specifically with a reflector with a photometric profile which matched that of the slab. The control gear for the fitting was placed within this recess so that the reflector end would not become too bulky. The fitting and control for the luminaire are completely hidden within the concrete reveal.

Most joints between mould and ply soffit were sealed with silicone - with the exception of between moulds a simple pvc tape joint was made. This tape joint was hidden by the fact that it sits within a recess. The tape deflected a lot, but a deflection of 2 mm over a 2 mm joint is pretty much invisible! A notable exception is at the column head; given our experience in Fingal, we decided to reduce the overall dimension of the column; to separate slightly the soffit plane from the column place and to permit the column to sit firmly below the rib, not coming up along the inside facade of the ribs. Given the tolerance in setting the moulds on the desk and the position of the column, the hole for the column had to be in the GRP oversized by 5 mm to ensure a fit. This hole was then filled with bondo and plugged from underneath so as to prevent any concrete from slipping out. In this detail the striking of the mould was critical; there had to be enough play to slip the mould out, while not making the small step in the column too low down. We calculated the slope of the rib's outer faces against the distance to work out exactly what the minimum dimension the step could be.

The reinforcing of the slab was slightly complicated by the fact that within each rib the links had to be graded; this was simply a question of mass producing 20 or so sets of different length links for the rib reinforcing. As everything was cast, all of the elements in the ceiling, such as down lights in the corridor areas, smoke detectors, fire alarms, heat sensors, pirs and so on, had to be located in the formwork. Positions always had to be cross checked with reinforcing locations as there were frequent clashes.

2. Precast Concrete Light Shelves

As I mentioned earlier, precast concrete units were designed as light shelves on the East elevation. The east elevation is really facing north; it has sun striking it only until about 10 am which we discovered through our thermal analysis, meant that though this is sufficient sun energy to counteract the effect of the night time purge, it does not justify a shading device such as a brise-soliel. Most of the time the problem is to maximize the ambient light of the sky, not control direct sunlight. For this reason a low sill height (400 mm), was set to increase the window dimension and a light coloured precast concrete light shelf, seen as an extension of the internal floor surface, was incorporated. These precise concrete elements were made from concrete cast with a Spanish Dolomite aggregate and were hung from corbels in the concrete upstands. In order to maintain their white colour, they are treated wit a Tensit, anti-graffiti varnish. The vertical section is basically a cladding panel, while the slightly inclined plane is separated from this vertical panel to allow water to pass through. The panels were made by Trent Concrete in the UK and shipped to Limerick on flat bed trucks. When they arrived on site, they were craned into position on the facade.



3. Atrium Structure: Precast Concrete Columns

The atrium structure consists of timber, glass and steel supported by precast concrete columns at the bottom and the building's concrete frame at the top. The atrium structure is basically a large brise-soliel that supports the glass wall enclosing the atrium. It's development was the subject of a long process of model making and environmental simulation which time does not permit us to go into here, however, it's development and construction were as involved as that of the concrete frame. The atrium space, a large glazed area, is anchored to the concrete frame and to precast concrete columns.

4. Structural Functioning of Structure - Load Paths

Two storey precast concrete columns are used to support the ground floor slab and the brise soliel. The column takes only horizontal loads from the facade. The roof structure of the atrium is cast into the concrete slab. Stainless steel cast-in brackets are positioned at the top and bottom of precast columns for fixing to the columns. The columns were made by Trent Concrete in the UK and shipped to Limerick.

The shape of the concrete we have used has been determined by a complex variety of factors, which work together to create a naturally sustainable building. We have not missed an opportunity to give a specific environmental function to form; we are interested in understanding the potential form of a material and a method of construction.