The Architectural Expression of Environmental Control Systems

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Central Library, Phoenix, Arizona, USA

From the cold temperate conditions of central Europe, we now move to the hot dry climate of the city of Phoenix, which is the capital of the south-western American state of Arizona. The new Central Library building is just north of the city centre, where N. Central Avenue crosses over the I-10 Freeway tunnel. With a total area of ~26 000m² (280 000 ft²) spread over five floors, the library is designed to house up to 1 million books. The first civic building completed (at a capital cost of just under US$100 ft²) as part of a plan to revitalise the downtown area, was opened in May 1995.

The designers

The successful design team (of the 25 or so who expressed an interest in this commission) was led by local architect Will Bruder, whose small practice was based at New River in the desert just north of Phoenix; in collaboration with Ove Arup California's large office, a block away from the intersection of the Santa Monica and San Diego Freeways in Los Angeles — an intriguing contrast in size and location.

A graduate in sculpture from the University of Wisconsin at Milwaukee, and a student of Paulo Solari, Bruder had started his own practice in 1974. He had a well-established philosophy that building systems were basic to architecture — in his view 'real architecture is a balance between pragmatism and poetry'. Expressive integration of environmental control systems and responding to the local climate and surroundings were always high on the agenda, whether he was designing houses, offices or libraries (Bruder; 1998). In two earlier branch libraries for
the city of Phoenix (at Mesquite and Cholla) Bruder had
tested many of the ideas, including the expression of
environmental control systems, which came to full fruition
in the Central Library project (Khosravian and Schutt, 1996),
where he was assisted by partner Wendell Burnette and
associate firm DWL Architects.

Ove Arup California gave Bruder an ‘exclusive’ on
this project. In other words, they were not involved with
any of the competing teams. In addition, Bruder took the
apparently unusual step of involving the engineers (Peter
Budd was principal at the time) in the initial interviews
with the client. In due course, the environmental engi-
neering design was taken over by Alan Locke, a graduate
of Napier College, Edinburgh, who had been engaged,
at Arup’s London office, to work on the Pompidou Centre
and the Lloyds of London projects, and later with Arup
California, on the design of the Mens Museum and the Cy
Twombly Gallery in Houston, Texas.

This was the first project on which the two practices
had teamed up, together with environmental design spe-
cialists David Tait on solar design and Roger Smith on
lighting.

Project background and the design process
The rapid growth of Phoenix has led to an expansion of
its cultural and community facilities over recent years. The
new Central Library is the flagship manifestation of what is
a US$1.1 billion dollar programme. The site of the build-
ing is on the north edge of the Margaret T. Hance Park
(or Deck Park), which itself is above the I-10 freeway
tunnel. Central Avenue runs alongside the west edge of
the site with only the sidewalk between road and building.
Surrounded by the upper Sonoran Desert, Phoenix is at
an elevation of ~330m and a latitude of 33.9°. It experi-
ences hot dry summers (1% design temperature of 42°C),
relatively mild winters (1% design temperature of 3°C),
and receives >85% of annual possible solar radiation

The brief was to emphasize low capital and running
costs (do not all briefs) as well as the elimination of the
operational inefficiencies of the existing library. The need
for energy efficiency was implicit and the design had to be
both flexible within its current envelope and capable of
future expansion. But all this was to come later, following
the selection of the design team. Selection in this instance
was a professional hiring process involving an interview
following an open invitation for expressions of interest,
rather than by a design competition. For Bruder, the inter-
view involved describing how he would approach the
project, the brief and the methodology, and integral to
the presentation was Ove Arup engineer Budd.

Will Bruder takes some pride in ‘having that disci-
pline not to preconceive’ (Bruder, 1998). Having been
selected to lead the design team his first action was
to go on a 10-day study tour to Europe, taking with him
his associate and co-designer Wendell Burnette, and
Carleton Van Deman, president of DWL Architects
with whom they had formed an alliance for the project. The
aim of this tour was to study relevant buildings (not
necessarily libraries at this stage). Included were work by
Calatrava and Scarpa in Zurich; Pompidou; Institut du
Monde Arabie, Chelcie House and Labrouste’s Bib-
lotique Nationale in Paris; a meeting with Herman
Hertzberger in Amsterdam; Mackintosh’s School of Art
in Glasgow; and finally, in London, Foster’s and Rogers’
ofices and tours of several buildings in which ‘Ove Arup
designers had been involved.

Following that, the design team conducted a series
of public meetings with different interest groups in the
Phoenix community, 26 in all, to assess their expectations
of the building (students, minority groups, business users,
historic concern groups, etc.). They then worked with the
library and at the end of this process produced a 650-
page brief of the building requirements.

The final stop, before we went on the design journey
(1996), was for key members of the design team, the library management group and relevant
city officials, to make a brie run of recent central library
facilities in North America – in particular, Dallas, Houston,
Broward County Florida, Atlanta, and Toronto. In each
case, members of the group played the (serious) part of a
customer trying to locate a particular piece of information or
a book, to evaluate how the building really worked in
practice. A predesign process every bit as rigorous as
what was to follow.

Although they had not previously worked together,
The Arup team quickly realized that he [Bruder] and his
collaborator Burnette believed in teamwork, bringing to the project great talent for investigating, exam-
ning, making decisions and re-examining, all very quickly
but not only schedules and budgets, but also ideas’
and ‘Will Bruder believes in total team collaboration, and
in the early design phases, not a single idea or suggestion
passed unexamined. Many alternatives were considered
and rejected before the final solution was agreed’ (Bolin
and Hamilton, 1996).

One of the early options was to design a concrete box with thick walls and minimal openings to
the sun – the desert adobe house concept. This was analyzed
throughfully by Arups, but eventually rejected on account of
the lack of views out to the north and south. A trombe
wall option was also considered for the south facade, but
it too was rejected. Central core plans were considered
and rejected on account of their restricted flexibility in
terms of future changes in internal layouts. The break-
through, according to members of the Arup groups, ‘came
during a design team meeting when a plan emerged
for a service zone on each side of a “warehouse for
books”’ (Bolin and Hamilton, 1996) – the so-called
“saddlebag” metaphor – resulting in a building with
facades and roof that responded appropriately to the
environment.

Of course, this was the first project that Bruder and	hese engineers had worked on together, and according
to Alan Locke of Ove Arup, who participated in the tour
of recent libraries and visited some of Bruder’s previous
work, building up a relationship takes time and initially it
was hard to read Will’s mind. However, he recognised
that Will wanted to make it perfect and an excellent
relationship was built up and has continued in further
project work. He also recognised one of the advantages
of working with an owner-architect (as opposed to a
larger partnership) – that final decisions could be made
more readily at the design team meetings (Locke, 1998).

As far as design team meetings were concerned,
these were held weekly or fortnightly, at New River or
South Sepulveda Boulevard as appropriate, with the
design leadership coming from Will and Wendell. In the
words of the former, we led … the design effort, and it
was our honour in bringing this purity of integration to
the occasion that everyone responded to, an integration
that took place ‘at the conceptual or even the pre-concept
level, not at the schematic or the design development
level’. In his view, ‘technical issues are not about being
crammed into a solution, they are about forming the solu-
tion’ (Bruder, 1998).

Design outcome and thermal environmental control systems
Much of the 26,000 m² floor area is contained in a five
storey rectangular plan block. Levels 1 and 2 are ~66 x
107m and house the main lending and reference depart-
ments (Figure 7.1). The three ~66 x 80m upper levels
(Figure 7.2) house administration (Level 3), special collec-
tions (Level 4) and the main reading room (Level 5) (Seal,
1996). The reading room (Figure 7.3) has a height of
~12m, all the other levels being a more conventional 3m.
An atrium space (~32 x 8m), containing three elevators
and the main stairs, is north of centre on the north-south
axis of the block.
The so-called saddlebags are on, and completely
cover, the east (Figure 7.4) and west (Plate 10) façades
of the building, other than where Levels 1 and 2 jut out
from the rest of the block over the I-10 freeway tunnel.
~8m wide at their maximum, these full-height, curved,
copper-clad containers house the building’s escape stairs,
service elevators, rest rooms and mechanical services,
leaving the rest of the floor plate substantially free of
associated vertical ducting (Figures 7.1 and 7.3).

While the entire building is air-conditioned, signific-
ant steps have been taken in the design of the façades
and roof to control the solar heat gain which is such a
significant factor in this desert region. Given the latitude
and climate of Phoenix, the likelihood of significant
internal heat gains from lights and people, and a deep
floor plan which precluded natural ventilation, coupled with a strong desire to keep energy costs to a minimum, the thermal environmental control strategy became one of reducing external heat gains, minimizing internal heat gains and installing an energy-efficient HVAC system.

The HVAC system central plant is comprised of two gas-fired 400 ton (1407kW) absorption chillers in the Level 1 plant room at the bottom of the east saddlebag (Figure 7.5), with two 600 ton (2110kW) cooling towers in the adjacent yard. These supply chilled water as required to the main air-handling units (AHUs) located at each level in the saddlebags. There are four AHUs per floor; two in each saddlebag with capacities in the range 3.8-7.6m² s⁻¹, thus reducing the need for vertical air circulation and increasing the flexibility of the system to cope with changing circumstances.

Supply air ducts from the AHUs penetrate the concrete wall and run parallel to it in the so-called ‘power-bellies’ before being ducted into the ceiling spaces in Levels 1-4 (Figure 7.7). Distribution into the spaces is via VAV units, which are equipped with electric reheat, and then through specially designed perforated ceiling panels (Figure 7.8), designed and tested at the maximum and minimum flow rates to ensure adequate air distribution and reduction of the day time heat gains (Figure 7.9).

The passive environmental control systems for the library are incorporated in its walls and roof — with the aim of minimising solar heat gains but without eliminating visual contact with the outside environment. Thus, the east and west façades are completely shrouded by the saddlebags, the north and south façades are totally double-glazed and the roof incorporates three types of skylight.

On the east and west, the reflective properties of the external copper cladding form a first line of defence against the year round morning and afternoon solar radiation (Figure 7.4). The depth of the saddlebags, naturally ventilated other than where stair or rest rooms intrude, provides a second barrier, while internally, the 12-inch thick concrete wall panels give sufficient thermal time lag and reduction of the daytime heat gains (Figure 7.10).

The fully glazed north façade is fitted with fixed external vertical shading. These take the form of Teflon-coated acrylic fabric sails and eliminate direct sun penetration between the spring and autumn equinoxes. The saddlebags jut out on each side of this façade and also provide useful shading during that half of the year (Plate 13).

The south façade is fitted with horizontal, externally mounted, aluminium louvres. These are computer-controlled to eliminate direct sun penetration, while maximising views and daylight (Figures 7.11 and 7.12).

The roof incorporates three systems of environmental control, all of which impact to some extent on thermal conditions in the Level 5 Reading Room and the Atrium Space. The first and simplest of these are two 0.76m-wide strip skylights running along above the east and west walls, washing them with daylight at any time of the day (Figure 7.9) and with sunlight at solar noon. The second comprises the ~1.2m diameter skylights above the tops of the columns which provide support for the roof (Figure 7.13). The blue interlayer within one of the several sheets of glass which form each skylight has a 4-inch (100mm) hole cut such that at solar noon at the summer solstice, the sun shines directly onto the top of the corresponding column. Finally, the nine atrium skylights (Figure 7.12) are designed to diffuse maximum daylight into that space using a computer-controlled double-louvre system — an upper set of reflective louvres tracks the sun and directs the appropriate amount of light downwards, while the lower set diffuses the light and eliminates direct glare to the space below (Figure 7.14).
Expression of environmental control systems

According to one writer, this is ‘One of the most technically expressive buildings in America’ (Barreneche, 1995), while another asserts that ‘... Bruder has managed to raise prosaic technology to the level of architecture by making it obey a formal order and by translating it into metaphorical terms corresponding to his concept of the public library as a late 20th-century popular institution’ (Curtis, 1995). High praise indeed from the pages of Architecture.

Outwardly an air-conditioned box, the library’s orientation and the clearly articulated differences between its façades, belie such a simplistic description. The saddlebags shroud the east and west façades, clearly expressing their thermal environmental control function of limiting solar heat gain to these façades, which not only bear the brunt of the sun’s intensity all through the summer months, but also are the more difficult to control. The fixed vertical
7.10 View down into the saddlebag at the north-east corner.

7.11 External detail of the south façade louvres at Level 2.

7.12 South façade with the louvres in their closed position.

7.13 Skylights. The row on top of the metal-clad structure is above the atrium, the others are placed above the structural columns.
shading on the fully glazed north façade, and the adjustable horizontal shading on the south, even to the use of fabric for the former and aluminum for the latter; speak directly, and appropriately, of their environmental control function – solar heat gain, daylighting and glare in this instance. The use of the saddlebags to house the main AHUs and vertical pipe runs, as well as other service areas, reinforces and also gives clear expression to their environmental control function.

In the words of the architect, it's obvious that the two sexiest things about this building are these saddlebags clad in copper and what was generated from that idea and the mystical quality of the great reading room ... which is a testament to structural and mechanical and lighting integration' (Bruder, 1998).

With the main items of central plant housed within the saddlebags, the cooling towers tucked in behind the high walls of the service yard, and air distribution via per-

forated ceilings on Levels 1–4, there is little of the active systems directly visible to the casual observer other than the floor diffusers in the reading room. Whereas the mechanisms of the adjustable louvres on the south façade and the atrium skylights are discernible only to the careful observer, it is understood that high noon at the time of the summer solstice is celebrated appropriately in the Reading Room by a (presumably capacity) crowd of 1500–2000 people. The set of electrical transformers serving the building form an interesting sort of sculpture court at ground level on the west side of the building (Plate 10), but may eventually be screened by surrounding shrubs.

Performance in practice and lessons learned

Energy efficiency was an important criteria for this building and according to Bolin and Hamilton (1996), the design heating and cooling load predictions were 10% less than Arizona State targets.

A group of Arizona State University (ASU) students undertook a study of the efficacy of some of the passive systems, concluding that 'even through internal sources of heat are the primary issues in internal load dominated buildings, envelope design is still critical in extreme climates' (like that of Phoenix, presumably) (Burelsem et al., 1998). The study also conducted computer simulations comparing a system of fixed louvres with the adjustable ones installed on the south façade, and removal of both the circular and the strip skylights from the roof of the Reading Room. In no case were the computed differences more than a few percentage points – well within, one might reasonably assume, the margin of error of even the most reliable of computer models – but the study did assert that a system of fixed louvres on the south façade could be 'as effective and less troublesome'. The same study investigated the potential for using evaporative cooling in some zones of the building where close humidity control was not deemed necessary, concluding that such a strategy had the potential for significant running cost savings.

For Wil Bruder, this project reinforced his conviction that the architect must accept the responsibility of leading the design team to be the composer of the symphony, the choreographer of the dance and that 'if you are challenging convention (even when in fact you are only going back to basics) you have to be prepared to be not just poetic about the intention, and win everyone's favour by the vision of your idea, but also be able to support it with incontrovertible technical rigour'. Alluding to a presentation he was about to make in relation to an upcoming major project, he described it thus.

So it's our job now to present a system that does have the qualities that we promise, to back up the built reality; and we have to bring the data, accurately projected, of the kind of savings that will be generated by letting us have our way with this, and the benefits to the client organisation and their whole culture, if you will, by accepting it. And so it's the start of this journey, and we'll be going from a conceptual level of schematics, through design development, but now's the time we win the audience, and then what's important to do is listen to your clients with their agenda, you know, give the proposition a language and a potential that captures their imaginations, empowers them to be part of the team from the beginning, and then you go on a journey excitedly together. Because, you know, people just don't like the ordinary, and I think they are rather thrilled with the potentials that we're talking about, portend, both for the quality of the environment that we'll provide and the energy savings; and the responsibility to the larger global issues; I mean I think it can be a win-win for everybody, but it takes an almost evangelical preacher attitude to empower, enlighten and inspire these people to the cause. (Bruder, 1998)
night-time ventilation, and evaporative cooling strategies are being proposed, so he and his colleagues will no doubt find themselves in that role again.

More prosaically, the student studies confirmed the need for the design of the basic building form to reduce solar heat gain in such a climate, while at the same time reinforcing the KISS ('Keep It Simple, Stupid') principle and demonstrating that later individual design changes may only have a small impact on overall energy efficiency.

Finally, at the irritation level, how to keep the local bird life out of the saddlebags needs to be given some careful design consideration (Figure 7.10). (I promised Building Operator Bill Ruhule that I'd make that point!)

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References


