SUSTAINABLE DESIGN HAS CHANGED BUILDING DESIGN

Ronald Mazza, P.Eng.[1]

INTRODUCTION

I have been a consulting structural engineer in Toronto for over 35 years and am a Senior Principal of Read Jones Christoffersen (RJC) Ltd., one of Canada's leading structural engineering firms, specializing in the design and restoration of building structures and cladding systems. In those 35 years, I have been involved in the design of a great number of both major and minor commercial and institutional building projects across Canada. These projects are undertaken by interdisciplinary teams consisting of owners; users; architects; structural, mechanical, and electrical engineers; landscape architects; cost consultants; project managers, etc.

The recent heightened interest in the design of "sustainable" buildings, driven by growing environmental and energy supply concerns and spurred by the introduction of measurement tools such as the Leadership in Energy and Environmental Design (LEED™), has triggered a fundamental change in the design process of these buildings. The integrated design process required by such projects is altering the way buildings are designed and constructed.

THE TRADITIONAL DESIGN PROCESS

Historically, the building design process has been a linear one. An owner needs a building so he engages an architect. The architect then determines the zoning requirements and functional needs of the owner, from which the general form and siting of the building are determined. This involves the massing of the building on the site, based on zoning and by-law requirements and size requirements. The functional planning is based on the interrelationships between various usages within the building. The general exterior appearance of the building is based on cost and aesthetics. This is the Schematic Design Phase and essentially fixes the building's shape and form.

If these parameters are acceptable, the building then moves into the Design Development Phase in which the design evolves further and the various systems of the building are added. This includes the development of a structural scheme to create the space, the mechanical system to provide heating and cooling, and an electrical system to provide power. Though all disciplines work on the same building, they operate amazingly independent of each other with the exception of certain points of overlap and conflict. The architect's role at this stage is to make sure that the conflicts are resolved, and that the various systems are deemed functional but essentially invisible to a user of the building, and that they are designed in a way that will not obstruct the use and functionality of the building. These various engineered systems are independently layered onto each other for the final design of the building.

There have been exceptional buildings that did not follow this process, however. These include buildings in which the structure was expressed as part of the architecture and, in some cases, even the mechanical components exposed as part of the appearance of the building. This has been a European design aesthetic for many years. In these types of projects, as exemplified by the work of such architects as Helmut Jahn of Chicago, in conjunction with German engineers Werner Sobek (structural) and Matthias Shuller (mechanical), the separate building systems are finely integrated. The Pompidou Centre in Paris, Figure 1, by Richard Rogers, Renzo Piano, and Gianfranco Franchini, is a classic 1970s example of the structure and the mechanical systems operating as an integral part of the architecture of the building.

However, in North America, these types of projects have been the exception rather than the rule. The majority of buildings constructed in the past 50 years are made up of separate and independent systems; the architecture is separated from the structure, and the mechanical and electrical systems separate from all the others. In most cases, the engineering systems were hidden behind the architectural finishes or

[1]Principal, Read Jones Christoffersen Ltd., Suite 500, 144 Front Street West Toronto, ON M5J 2L7, Canada. Office: 416 977-5335 ext 228. Fax: 416 977-1427. Email: rmazza@rjc.ca.

FIGURE 1. Pompidou Centre, Paris.

placed in separate rooms, ducts, or shafts, invisible to the building occupant.

The energy crisis of the 1970s generated a move towards more energy-efficient buildings. This move, however, was focused on improved energy efficiency of the mechanical systems and cladding systems to reduce energy use and attendant operating costs. These improvements were primarily applied to these separate disciplines with minimal inter-relationships between them, or with other aspects of the building.

WHAT'S CHANGED

In the last decade there has been a rapidly increasing awareness of the impending global crises with respect to the availability of cheap and easily accessible energy sources, combined with a rising concern about the global warming effects of excessive CO_2 emissions into the atmosphere. Buildings in North America are now increasingly recognized as being the source of almost half of CO_2 emissions and 70% of electricity demand. This has resulted in a movement in the building industry toward the design and construction of so-called "sustainable" buildings. In North America this concern has been focused largely by the United States Green Building Council (USGBC), resulting in the development of the Leadership In Energy and Environmental Design (LEED) requirements for sustainable buildings. Originally launched in the year 2000, the LEED™ green building rating system has revolutionized the way sustainable buildings are designed in the US and Canada. Not just focusing on energy use, but considering other aspects of the buildings such as the site, water efficiency, emissions, materials use, and indoor environmental quality, has been the hallmark of the LEED point system for rating a building's sustainability.

The design of better quality buildings is evolving so rapidly that in many circles the achievement of LEED™ requirements is now considered insufficient to deal with our looming energy and environmental crises. A LEED™ Silver building is now considered a better building but by no means a good building. There is now a growing movement within the design community towards net zero buildings, buildings that either do not require energy from any fossil fuel source or have a zero carbon footprint.

Though only seven years old and subject to much criticism, LEED™ has succeeded in what it set out to do, i.e., to transform the construction industry. It has created the most profound changes in the method of building design in the past 50 years, at least in North America.

THE INTEGRATED DESIGN PROCESS

Previously, our primary concern as structural engineers was to create a cost effective structure and a column grid and wall locations to minimize the impact on the floor usage. We needed to coordinate with the mechanical engineer sufficiently to minimize the floor-to-floor height and provide sufficient ceiling space for the mechanical systems. Beyond that, economy was usually the driving force behind the selection of the structural system.

Today the rules are changing. Sustainable buildings, if properly designed, must be viewed in a holistic sense rather than as a conglomeration of separate systems. It is no longer acceptable to design the building out of context of its location and surroundings. A building in Houston cannot be identical to a building in Edmonton, Canada. Rather, they need to respond much more directly to their individual environments to attain the efficiencies we have come to expect. The whole building is now increasingly being designed as a single organism; an organism that provides a better quality, healthier, more productive indoor environment while at the same time operating with minimal fossil fuel demand. This means that the individual components of the building, including the architectural elements, the structure, and the mechanical systems are required to be interlinked as never before.

This design process involves all team members including the building owners, occupants, and operators sitting down together in a design charrette at the early design concept stage to determine holistically how this new building, this new "organism," is going to work. The questions posed for the building at this stage include:

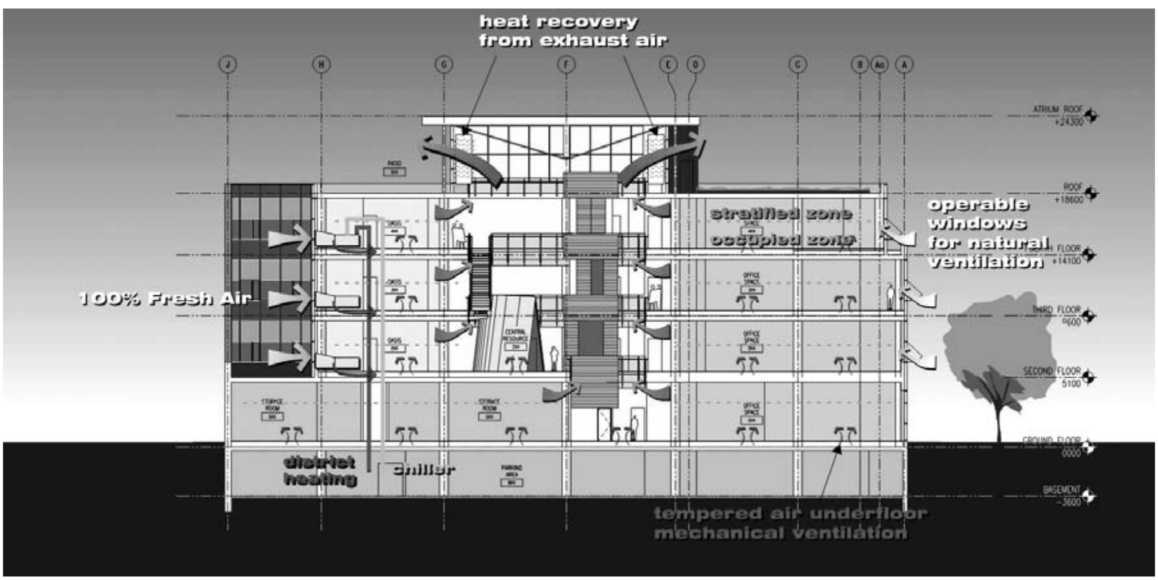
- How will the building respond to its site?
- How will it utilize local materials with minimum CO_2 production?
- How will it maximize the use of natural light?
- How will it provide heating and cooling with minimum or no CO_2 generation?
- How will it provide fresh air?
- How will it reduce or eliminate waste?

All this is required in addition to the basic need of providing a functional space. All elements of the building now interact in a manner that maximizes efficiency and eliminates redundancy. An initial product of the process is usually a simple but effective "cartoon" of the entire building showing how it operates as an interconnected whole. Figure 2 is an example of a cartoon developed during the design of the Jean Cansfield Government of Canada Building in Charlottetown, Prince Edward Island. Previously, this was seldom executed, as there was little or no interconnection of the individual system.

This design charrette process is now a fundamental and essential part of designing sustainable buildings and will likely become the standard process for designing all good quality buildings in the future. It is the most fundamental change in the design process that has occurred in recent years. It requires ALL team members to actively participate and fully understand the objectives of the project and the interaction of all systems in the building. This is where the most fundamental aspects of the overall operation of the building evolve, where the building systems and their interdependencies are discussed, with options weighed and solutions selected. This is where the full interactive, interdisciplinary operating principles of this new "organism" are determined and fixed.

The reduction or elimination of separate building finishes minimizes material use. Ceilings are eliminated in favour of raised floor systems. The underside of the structure is exposed and becomes the ceiling. The mass of the structure is incorporated into the mechanical systems as heat sinks and heating and cooling piping systems are embedded in the slabs. The slab soffits are designed to maximize the penetration of daylight and reflect indirect artificial light.

FIGURE 2. Jean Cansfield Government of Canada Building, Charlottetown. Building Cartoon Showing Natural Ventilation Flows.



There is no longer a clear demarcation between the separate elements and design disciplines of a building. Therefore, all players in the team are required to be involved from the very beginning in the development of the concepts and design of the building and are expected to contribute and be knowledgeable not only about their own disciplines but the impact of other disciplines on their design team. This makes the design of the building both more complex and more time consuming—and much more fun.

One result of this integration of systems is that the structure is now being asked to do more than simply support its required loading, have minimum impact on the space configuration, and be as economical as possible. The structure is now expected to be part of the architectural expression, part of the mechanical system, and part of the lighting system. With the absence of ceilings, the underside of the structural slab is now becoming the visible element in the space. These slab soffits must now meet an aesthetic requirement.

An early example of this integration involving our firm was architect Moshe Safdie/Downs Archambault's 1995 Library Square Project for the City of Vancouver for which Read Jones Christoffersen was the Structural Engineer. This monumental building, occupying a full city block, houses Vancouver's new main library within a nine-story, 400,000 ft^2 oval building adjacent to a 20-story, 300,000 ft^2 office portion. As shown in Figure 3, the concave curved face of the office tower runs beside the convex curve of the library, and the high atrium space this created is covered by a skylight structure spanning 66 feet at the eighth floor. This was a pioneering use of a raised floor air distribution system, eliminating the need for a ceiling.

FIGURE 3. Library Square, Vancouver. Skylight and Atrium.

As shown in Figure 4, the architects and structural engineers articulated the underside of the exposed cast in place to concrete a floor structure to form a series of shallow barrel vaults that were not only structurally efficient but were also used to reflect the indirect lighting of the building and give a strong repeated three dimensional architectural form to these "ceilings." The structure is the ceiling.

More recently, on another of our projects, architects Diamond and Schmitt exposed the slab soffits of the new Bahen Centre, Figure 5, for Information Technologies building at the University of Toronto in a similar manner. This building also incorporated a raised floor mechanical system with indirect reflected lighting and no separate ceiling. A 12-inch thick cast-in-place reinforced concrete flat plate floor structure was selected not only as an efficient structural system but also for its desirable mass for the heating and cooling requirements of the building. Again, the soffit of the structural slab was now the exposed ceiling. To give these now exposed slab soffits more visual def-

FIGURE 4. Library Square, Vancouver. Concrete Formwork for Exposed Barrel Vault Ceiling.

FIGURE 5. Bahen Centre, University of Toronto.

inition, corrugated forms were added to the underside of the slab, as seen in Figure 6, breaking the monotony of the flat slab surface.

As we are breaking new ground here, unexpected situations can arise. This increased integration of the individual building systems could lead to unanticipated problems with previously unheard of impacts for the structural designers.

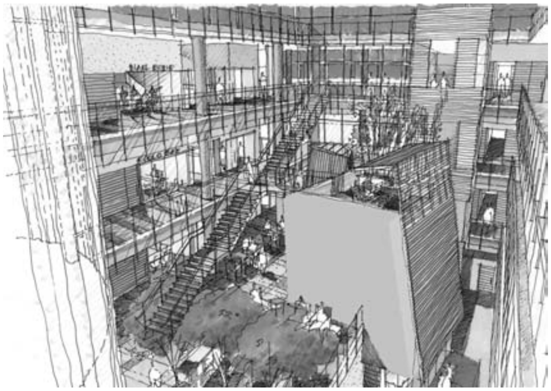
An example is the recent Jean Cansfield Government of Canada building on Prince Edward Island, Figure 7, which was designed by architects HOK Canada and Guimmond Hammerlund Jones in joint venture with Read Jones Christopherson, the structural engineers. The design charrette cartoon for this building was shown in Figure 2. The concrete floor slabs were exposed and were used as a heat sink with heating and cooling radiant piping placed within the slab. A raised floor distribution system, shown in Figure 8, was also used, and therefore no separate ceiling system was incorporated. Again, the ceiling was the concrete flat slab soffit.

FIGURE 6. Bahen Centre, University of Toronto.Exposed Slab Soffits with Cast-in-place Corrugations.

In this case, a concern was raised late in the design process about the possibility of excessive sound transmission within the floor areas. Such a problem can arise as a result of large areas of exposed flat concrete slab surfaces within office environments. With the use of traditional suspended acoustic tile ceiling normally used, this problem does not occur. However, with large exposed areas of concrete, the provision of adequate acoustic absorption is not easy to execute. Since the slab was being utilized as part of the radiant heat system, the application of acoustic material on the slab soffit was not desirable due to its insulating

FIGURE 7. Jean Cansfield Government of Canada Building, Charlottetown.

FIGURE 8. Jean Cansfield Government of Canada Building, Charlottetown Central Atrium.



properties. Similarly, hanging acoustically absorbent baffles vertically from the slab was not feasible, as it would interfere with the natural light penetration into the building and the reflection of the slab soffits.

The solution, in the end, was a structural one. Acoustic metal deck was cast into the slab soffit on top of the formwork system. Acoustic metal deck has a high thermal transmission and therefore does not interfere with the radiant heating and cooling within the slab, but it absorbs sound efficiently in order to ease the acoustic concerns. Only in a fully integrated building does an acoustic concern become a structural concern and an acoustic problem require a structural solution. This would not normally have occurred previously.

Architects and consultants who understand the integrated design process can work very well together in developing a building system that has minimum carbon demands, as well as a healthier and more inviting environment to live and work.

EVOLVING DESIGN TOOLS

Increased computing capabilities are having a dramatic impact on the design of better quality buildings and are being utilized as never before. Energy modeling of buildings is mandatory under LEED. The rapid evolution of increasingly sophisticated, accurate, and easy-to-use energy modeling software now allows the investigation of many building design options, with different building system combinations and permutations in order to hone in on the most cost effective and efficient solution for a particular building on a particular site. These tools did not exist 10 years ago.

The rapid evolution of Building Information Modeling (BIM) software, such as Autodesk's Revit Architecture, promises to further revolutionize the design process of buildings by taking the integrated design process to new levels of sophistication and capability. It will facilitate a fully integrated design and construction process. Existing design and drafting software mirror the traditional separate sequential or parallel design process with little interaction and integration of disciplines. Unlike existing separate computer-aided drafting (CAD), energy modeling, and structural analysis software, BIM systems will have the potential to create a fully unified and shared database model of a building integrating all systems in a single digital model. For the first time, all the building systems will be represented in their full relationship to each other. This is the building "cartoon" in a detailed, changeable, fully integrated, and digital form. This, in conjunction with the increasingly sophisticated energy modeling and building behavioural tools that are now being plugged into the BIM systems, allows the creation and testing of fully combined building systems rapidly and inexpensively. Building designers can now quickly model and test alternatives and system combinations. This revolution in the design process is the next big step.

SUMMARY

In order to design truly sustainable buildings, it is necessary that all members of the design team work in a fully integrated fashion and that the building be viewed as an integrated whole. Individual building systems no longer exist independent of each other but are increasingly heavily linked across disciplines. The structural elements are required to form both architectural, mechanical heating and cooling functions, and lighting. This makes the design of a sustainable building a much more challenging and cross-disciplinary process than in the past. Changes or problems in one discipline cannot be readily rectified or instituted without impacting the other disciplines, which are now linked together in ways never before undertaken in building design. New computer design tools such as energy modeling and Building Information Modeling (BIM) will provide even more incentive and the capability to work in fully integrated design teams to create more environmentally-sound, high performance buildings.