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Sustainable Building Design Case history C.K. Choi Building, UBC

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Summary

This paper describes the challenges and successes of the design of the C.K. Choi Building, for the University of British Columbia in Vancouver, Canada. This building, for the Institute of Asian Research, was designed in 1993. The University wanted a building which would set new standards for sustainable design, construction and operation. The building was to have a minimum impact on the environment. The design team set out to create a building with a strong commitment to using recycled and recyclable materials, and focus on effective waste management, water and energy conservation. The building was to serve as an office building to house five research centres for China, Japan, Korea, Southeast Asia and South Asia. Completed in 1996, the C.K. Choi Building uses energy efficient systems and recycled materials previously unseen in Canada. It remains today one of the most comprehensive buildings of its kind in Canada even though it is six years old.

Keywords: Sustainable Building Design, structural design, recycled construction materials, timber grading, holistic, durability, longevity

Fig. 1 East Elevation

Fig. 2 View from Clerestory Window

1. Design Approach

A new, holistic approach was taken to the design of the C.K. Choi Building. At the outset of the design, charrettes and seminars were held to explore, learn and establish the goals for the project. It was a learning experience for all involved to establish what is meant by 'sustainable design' and how these concepts could be converted into achievable goals. Experts were invited to speak to the team and be part of the brainstorming sessions. The team of design professionals: architectural, landscaping, structural, mechanical and electrical and cost consultants, worked together with all the stakeholders, including the University representatives and building users, to set out the sustainable goals of the project. As the design progressed, all decisions made in the process were measured against these goals. However, this process at the outset of the project not only served to set goals. The process contributed to building team spirit and collaboration between the parties involved in the design and decision-making disciplines. This is vital to success in designing a sustainable building as the work of each affects another. It is important to be aware of objectives and needs of all disciplines so that opportunities in the design process are seized and potential conflicts are minimized.

As the project progressed, the team expanded to include the building authorities and contractors. Again, the importance of working together to find solutions became apparent. There was not always consensus on the goals that had been set. As a result the approvals required to implement the goals from various Authorities having jurisdiction both within the University and outside had to be fought for one by one. Also achieving these goals often meant deviating from the building codes and returning to first principles of design. This involved research by the design team and discussions with the building authorities to ensure that the intent of the code was met and safety standards maintained. Building codes in Canada currently are not set up for the use of recycled materials, alternate water and sewer systems. A large part of the challenge in building sustainability lies in working to bring about change and working together with building authorities to achieve common goals.

2. Goals

The following goals were set by the design team, university representatives and users at the project outset and monitored through the design process:

2.1 Design a Building Maximizing Existing Material Resources

- Use materials that were 50% reused or recycled content.
- Consider the recyclability of the building.
- Select new materials with low embodied energy.
- Significantly reduce the construction waste through process and recycling.

2.2 Design a Building to Minimize the Impact on Energy, Water and Systems

- Reduce the energy consumption of the building to 50% below ASHRAE/IES 90. (American Society of Heating, Refrigerating and Air Conditioning Engineers/Illuminating Engineering Society). This American Standard - the most current standard at the time of design - establishes minimum requirements for the energy efficient design of buildings.
- Reduce water supply to the site by 50% compared to a conventionally designed building.
- Eliminate the need for a sewer connection.

2.3 Design for Longevity of the Building

- Detail and design for a 200-year expected life of the building.
- Create a flexible design which can adapt over time to changing occupants and uses in the building.
- Select material and finishes in the building that minimize non-desirable emissions in the building.
- Optimize the indoor air quality.

3. Site and Building Description

The site provided by the University was a fairly large area, 36 m by 92 m. However, the design team decided that it was important to preserve as much of the forest as possible that covered the site. Subsequently, the site was reduced to 18 m by 92 m, this being the area of an existing parking lot on the site. The 30-m tall forest trees remained untouched on the site. Use of the forested area that bounded the west side of the building was made throughout the design. The building was oriented to take advantage of natural light and shading provided by the forest to reduce heat gain and glare. The building is a long thin shape (a footprint of 11.5 by 88 metres). The building shape was a result of a number of factors, some of which were; the desire to keep the forest intact, the desire to maximize daylight into the building reducing energy consumption, and a response to the available salvaged timber used for the structural frame.

The building is a three-storey, 3000 m² office building. The five research centres occupy five atria areas with five distinct raised, curved roofs. A central meeting area ties these research areas together. The building has a flexible layout for research and to allow for future changes and uses in the building.

The structure of the building is constructed using predominantly reused timber for the main beams and columns. The floors are constructed using steel deck and lightweight concrete topping minimizing the weight and quantity of material used. The roofs are curved glulaminated beams with roof deck. The stair and elevator cores are concrete. They provide natural elements to resist seismic forces. Some additional interior concrete shearwalls were also added. These concrete walls also act as noise barriers around the stairs, elevator and washrooms as well as a heat sink. The foundations and the slab-on-grade are also concrete.

4. A Detailed Look at the Structure

As the design for our building began, an existing building on the University campus, the Armouries, was about to be demolished. The Armouries contained 70-year-old timber trusses. After initial inspection of quality and condition of the timber, the decision was made to salvage and use them to form the structure of the new building. As structural engineers on the project, this provided a set of challenges and changes to the design approach. The trusses were deconstructed carefully, removing the connections and denailing. Then each piece of timber was catalogued with size and length. At this point, the timber was visually graded to establish generally the wood type and an initial grade. The wood was graded as Douglas Fir, select structural (top grade). The timber were stored on site, and protected until construction of the building began.

Fig. 3 Existing Armouries Building

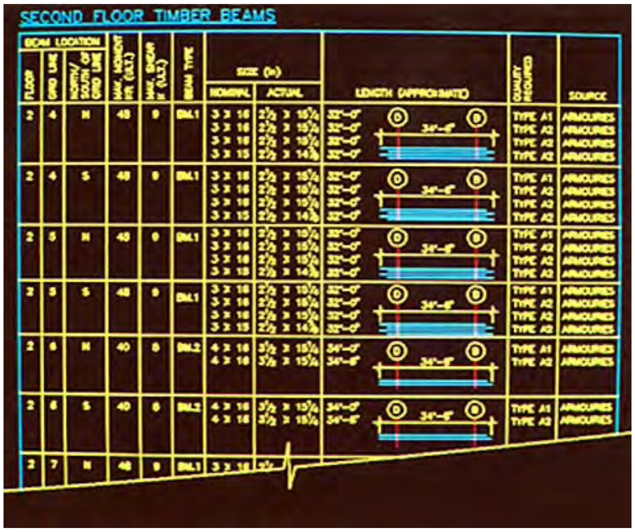

Fig. 4 Excerpt from the Timber Inventory

This began the generation of the building grid. Working with the team, the structural system and layout of columns was established to suit the available lengths and sizes and initial grading of these existing timber. A drawing in the form of an inventory was produced. This inventory showed all the timber in the building, indicating their location, size, length, source, moment and shear capacity with the assumed grade. The purpose of this inventory was for speed of final design. Specific grading of each piece of timber was scheduled at the start of the construction process. At the time of the design an educated assumption of the strength of the timber was made. At the time of grading and construction the inventory enabled quick verification of the desired strength of the timber or if specific pieces of timber had to be relocated.

The structural system consisted of timber columns, three storeys in height with splice connections as required. Timber beams were combined to achieve the strengths for the loads and spans to form the structure for the floors. These were then connected each side of the columns. All the steel connections were of recycled steel and were designed to be demountable in the future, should the building ever be deconstructed. At this time back in 1993 structural steel was available with recycled content. However, it proved difficult to obtain mill certificates verifying both the source of steel and the recycled content used for fabrication. It took considerable work and tracking to be able to verify the goal of having 100% of the structural steel angles, plates, flat and round bars, and channels with 75% of recycled content.

At this point, additional challenges were encountered, some with the use of the existing timber. In order to achieve the required strength and to meet the minimum size code requirements for ‘heavy timber beams’, the existing timber were bolted together to form thicker sections. However the Building Authorities did not initially agree that this met the heavy timber code requirements for fire rating. As the reuse of the existing timber was crucial to the whole design concept, this presented a serious roadblock to the team. Investigation and research followed to present the philosophy to the authorities that the intent of the fire code was being met and the safety of the occupants was not compromised. The final solution accepted by the Building Authorities was to bolt together the individual beams, recessing the bolts and covering the bolt heads with wooden plugs.

The second crucial challenge with the use of the existing Armouries timber came at the start of the construction process. At this point, the timber were taken to the contractor’s yard to be cleaned, sorted and fabricated. A more detailed grading process at this time took place. Conventional grading rules take into account all the flaws in the timber including the existing bolt holes from the original connections. Subsequently, a large number of the beams were given a low stress grade. The initial design had assumed a better quality of timber and redesign with the weaker timber would result in a shortage of material. Since the inventory established where the timber was to be located, the timber could be regraded to suit the stresses in the beams. In addition, deficient areas were repaired using lag bolts and nails. In this way the portions of timber that had been flawed or repaired could be placed in non-critical locations. As structural engineers, the expertise in understanding materials and structure was used to utilize almost all of the salvaged timber in the new building. In the final design, 70% of the heavy timber in the building was reused timber from the Armouries.

Fig. 5 East Elevation Under Construction

Fig. 6 Southeast Elevation Under Construction

Concrete was also used fairly extensively on the project for the foundations, slab-on-grade, shearwalls and topping for the floors. Although, the production of cement powder for concrete is energy intensive, there are many reasons environmentally to use concrete. Among these reasons are, that for Vancouver, it is a locally produced and manufactured material. If properly placed and cured, concrete can be a very durable material and hence have a potentially long life span. It also can be left exposed, eliminating the need for finishes. The concrete walls and much of the floor were left exposed. There are no wasted materials as unused concrete are used, for example to make precast elements. It is also a recyclable material, often being used as road base or as recycled aggregate.

Steps were taken to 'green up' the concrete to lessen the negative impact of the material. Research was done to reduce the cement in the concrete by adding fly ash, a waste product from the coal industry. Fly ash can be used to substitute cement in fairly high percentages particularly in elements such as foundations. Our specifications were written to maximize the use of fly ash and silica fume in the concrete. Reinforcing steel with a high recycled content was also specified.

The design also focused on minimizing materials. The spans for the beams and slabs were optimized, with no column transfers. The design was refined to further reduce materials. Staggering the timber beams sandwiched together and grading the beams to suit their use in the structure achieved this. The deck was also designed to act compositely with the timber beams. The design also sought to minimize the weight of the materials, which had the effect of reducing structural sizes, including seismic elements and foundations. This was achieved in part by the use of deck with the concrete topping, lightweight topping, and the minimum use of finishes. Eliminating and reducing finishes also has the positive effect of using less materials. The building has exposed structure throughout. In many areas the floors are polished concrete, the ceilings are painted steel deck, the timber beams and connections are all visible. As a result the interior is aesthetically pleasing.

The C.K. Choi Building is designed and detailed to be a 200-year or more building. The longevity of the building is fundamental to the concept of sustainable design. By designing the shell of the building to last for 200 years, significant savings in energy, materials, pollution and waste are made. This was achieved in a number of ways. The timber is detailed to be protected from the elements and the University has a committed maintenance program to preserve and prevent decay of the building. The design also focused on a flexible layout to accommodate future changes in use and prevent the building becoming obsolete. The team sought to design a space that would make people want to preserve the building and hence ensure its longevity.

5. Unique Building Features

The building incorporates more than 50% recycled materials. As discussed above, the main structure is constructed using timber from an existing building at the University. However, in addition to that, the cladding was 100% reused red brick from a demolished building in downtown Vancouver. Interior items such as office doors and frames, aluminum handrails, toilet partitions, washroom sinks, paper towel dispensers and electrical conduit were reused from demolished buildings. Considerable effort was exerted to source, track and purchase the materials as they became available. Difficulties lay in both getting approval and funding to purchase the materials and in finding locations to store the materials. Much of the sourcing was done well before the contractor was involved. The process was time consuming and challenging since often the funding approval did not happen in time to purchase the materials. As the use of recycled materials becomes more mainstream an industry of dealers in recycled materials is emerging, so that the challenges related to sourcing will be made easier.

Where the use of reused materials was not possible the team researched materials with recycled content. The specifications had minimum requirements for % recycled content for many materials. In addition to the structural materials discussed the insulation, gypsum wall boards, carpets and floor tiles all have recycled content.

A rigorous plan was set up to recycle waste during the construction process. Bins were provided on site to separate the waste materials such as timber, structural steel, reinforcing steel, gypsum wall board, and cardboard before transporting to the recycling depots. The process was highly successful, diverting nearly 95% of the construction waste from landfill.

Energy savings were achieved both mechanically and electrically and the goals met. The buildings configuration, and clerestorey windows considerably reduced the use of energy for lighting. These aspects maximized the use of daylighting. Light coloured finishes reflect light within the building decreasing the need for additional light. Light sensors and manually operated occupancy sensors were also installed. Energy savings in the heating and cooling of the building were achieved also by the buildings orientation and use of the forest to shade the west side of the building. The walls and windows have excellent insulation qualities. The concrete was used as a heat sink. The atria including the central area create a stack effect for natural ventilation. The buildings' cooling relies on this ventilation with a few fans assisting in the air flow. The curved roofs were designed and oriented to receive photo-voltaic panels at a future time which will further reduce energy consumption.

Composting toilets were installed in the building, saving 1000 to 1500 gallons of water/day. City water is only required for the low flow taps and sinks. The site is irrigated using collected rainwater and recycled greywater from the building.

The health and comfort of the occupants of the building is also tied in with the concept of longevity of the structure. If a building is a pleasant and healthy place to be it is more likely that the building will last many years. The team designing the C.K. Choi Building focused on selecting materials and finishes that minimized toxic, nondesirable emissions in the building. Paints used were specified to be nontoxic, carpets to be formaldehyde free. The natural ventilation for the building maximized air changes to optimize the quality of the indoor air.

6. Costs

The budget was set for the project before the decision was made to develop the building as a demonstration of sustainable design. The design and construction had to be achieved without any adjustments to the original budget or schedule. The building budget was set at CDN $4.5 million and the building came in on budget.

The success of this has led the University to adopt the same process for other academic buildings. Designing a sustainable building is the same as designing a conventional building. Financial constraints are set by the budget and part of the responsibility of the design team is to keep within the budget. By setting clear goals from the outset of the design of the C.K. Choi Building and having a committed and focused design team, the building did not cost more than a conventionally designed building.

7. Discussion and Conclusions

The occupants of the building have been in the building for nearly six years. So far it is working well. There is, however, education necessary for the users of sustainable buildings. The building is naturally ventilated with openable windows and this is a significant change from a mechanically-sealed environment. Users and the maintenance personnel need to understand how the systems work and how to maximize their potential. Commissioning of the building was part of the process for the C.K. Choi Building. Sessions were held with UBC maintenance to discuss the building's operations and maintenance. There are maintenance manuals for the building. Also, each user has a document describing how the building works and the part they can play in maintaining the building's efficient operation. The occupants enjoy working in the building; the amount of natural daylighting is particularly pleasing. The only issue that some occupants have had is one of a lack of privacy due to the open plan, flexible layout. Communication on all these issues is key.

The University of British Columbia envisioned a building that would set new standards for sustainable design, construction and operation. The resulting C.K. Choi Building exceeded their goals and has led the way for sustainable building in Western Canada.

Acknowledgments

Client: University of British Columbia
Architect: Matsuzaki Wright Architects
Structural: Read Jones Christoffersen Ltd
Mechanical: Keen Engineering Co Ltd
Electrical: Robert Freundlich & Associates Ltd
Landscape: Cornelia Hahn Oberlander
Contractor: Country West Construction Ltd
Photographer: Mike Sherman

Fig. 7 Southeast Elevation