Rethinking Curtainwalls

Curtainwall Optimization Strategies for Circular Façade Design

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Focus and restrictions – Strategies for designing circular curtainwall façades based on waste reduction.

Abstract – Circular business models for building enclosures are gaining popularity as a performance based approach to architecture, designing facades for temporary lease to be disassembled and reused. As this model is contradictory to the design of typical building enclosures, which are meant to be exceptionally resilient and durable, key design changes can be made to take advantage of a reduced assembly life span to limit waste, which represents a considerable fraction of the carbon footprint of any given enclosure. This paper begins with an evaluation of life-cycle-analysis data for common curtainwall components and their repercussions in the context of a circular business model. Then, outlining strategies for optimized waste management, it proposes how they can be applied to curtainwall façades designed for circular use, focusing on the balance of performance and waste management, the capitalization of limited service-terms for strategic material use, and current infrastructural challenges of processes adhering to a cradle-to-cradle agenda.

Key words – Curtainwall, Façades, Waste Management, Circular Architecture, Recycling, Reuse, Cradle to Cradle

1 Introduction

Building enclosures are subject to harsh and volatile conditions, and as such, are traditionally designed to be durable. While the curtainwall is appraised for qualities including aesthetic and natural lighting, its intricate parts and inherent delicate nature relative to most archetypal building enclosures has rendered it the subject of a tremendous amount of research geared towards improving its serviceable life-span (Memari, 2013). The introduction of circular business models in architecture, which lease architectural components on performance based contracts that can be as short as several years, flips the ideal of the ever-resilient enclosure on its head and introduces a new paradigm that calls for a re-evaluation of the way we think about designing sustainable curtainwalls.

Circular architecture introduces the possibility of reducing material waste by capitalizing on short term applications (Durmisevic, 2010). This paper explores waste management strategies and proposes how they could be optimized in circular curtainwall design. First, life-cycle data for various curtainwall components is assessed in the context of a typical curtainwall. Then, exploring the challenges and advantages of waste management options, this paper outlines strategies to optimize curtainwall design for circular use, starting at the level of the architectural industry, followed by the level of a curtainwall assembly, and finally at the level of componentry.

2 Methodology

The resources explored in this paper were focused on curtainwall standards, components, waste management, and design for disassembly. Keywords *Recycling*, *Reuse*, *Refurbishment*, and *Life Cycle Analysis* were used, often in conjunction with keywords such as *Architecture*, *Façade*, and *Curtainwall,* to uncover standard practices for waste management in architecture. Keywords such as *Cradle to Cradle* and *Design for Disassembly* were used to find resources pertaining to circular practices.

Standards found via NEN Connect were used as references for curtainwall standards. Books found via Worldcat Discovery were referenced to compile information concerning waste management and circular architecture, and applied to information on curtainwall design from reliable organizations supported by subject matter experts.

3 Curtainwall Durability – Typical vs. Circular Objectives

A search in European and American building codes quickly reveals an underlying objective that façades should, with maintenance, strive to be as durable as possible (International Code Council, 2012; European Commitee for Standardization, 2015). While these standards aim to develop systems that are capable of lasting until the end of the serviceable life of the building, Ashby (2013) outlines different facets of durability that ultimately undermine the physical resilience of a product, namely its functional, technological, economical, legal and desirable lifespans.

Berge, who recognizes the value of the flexibility afforded by the aforementioned facets of durability in circular architecture, proposes the concept that quality design is focused "optimum rather than maximum durability" (Berge, 2009). Durmisevic correspondingly proposes the "decoupling of slow and fast time levels" (Durmisevic, 2010, p. 93) as a first step in the optimization of an assembly. This is particularly relevant in curtainwall design, where the serviceable lifespan of various components is drastically different.

European curtainwall standards divide curtainwall components into two categories: primary components such as framing members, framing hardware and fixings, which have a service life of either at least 50 years or equivalent to that of the building; and secondary components such as glazing, infill panels, gaskets, and sealants, which will require repair or replacement during that time (European Commitee for Standardization, 2015). Even within this secondary group, however, there is substantial disparity. For example, insulated glazing units have a lifespan that ranges from 4 to 35 (Berge, 2009), vacuum insulated units from 30-50 years, (Canada Mortgage and Housing Corporation, 2004), sealants from 10 to 15 years (National Institute of Building Sciences, 2016), and setting blocks from 10 to 50 years (Berge, 2009).

These variances in lifespan for curtainwall components leave plenty of room for optimization. Their application in a circular building enclosure, for which a single application can be as short as 1 or 5 years, benefits from the flexibility that comes from refurbishment being an integral part of the product (Durmisevic, 2010). In order to take advantage of this flexibility, however, it is crucial to understand waste management options, requirements, implications and challenges.

4 Overview of Waste Management Practices in the Context of Circular Architecture

While there is varying terminology for the classification of waste management options, they are generally divided into five overarching categories: *Reuse*, where a product is repurposed without having to be reverted to material form for reprocessing; *Recycling*, where materials are recovered and remanufactured at a similar quality level; *Downcycling*, where materials are recovered and remanufactured at a lower quality level; *Combustion*, where materials are combusted for heat recovery; and *landfill*, where the product is disposed of.

There is also general consensus on the hierarchy of these processes from a circular perspective. Re-use is the preferred option because it requires little to no processing energy or cost (Durmisevic, 2010), followed by recycling. Ashby's principle argument for the merit of recycling is that it is the only waste management strategy "that can [return waste material] at a rate that, potentially is comparable with that at which the waste was generated" (Ashby, 2013, p.85). On a similar note, Berge notes that "a product that can be easily recycled will normally be preferable to a product that is initially quite 'green' but cannot be recycled" (Berge, 2009, p. 13). While combustion has merit in particular circumstances, both combustion and landfill are contradictory to principles of circular architecture and will not be further discussed in this paper.

5 Optimizing Waste Management in the Architectural Industry

While the architectural community generally agrees that waste reduction is a positive endeavour, and strives to increase the fraction of products that we reuse and recycle (Berge, 2009), the reality remains that one of the biggest challenges pertaining to the reduction of architectural waste is that it is costly. While some recycling operations are undertaken because they are profitable (Ashby, 2013), much of the existing recycling infrastructure is largely thanks to economic incentives or penalties (Barton, 1979). To facilitate recycling at an industry level, additional incentives and disincentives in combination with stricter waste management regulations (Berge, 2009), particularly in demolition, would result in significantly more recycling, and thus further improve the overall economy of recycling. Documents such as "*diagnostic portant sur la gestion des déchets issus de la démolition de categories de bâtiments*", which is a demolition guideline with exceptionally high waste management standards, already exist in hopes of being adopted or referenced as legislative (Binamé & De Doncker, 2009).

6 Optimizing Curtainwall Assemblies

The optimization of circular curtainwall assemblies involves three primary strategies: design for disassembly, prefabrication and redundant recycling processes. While the first two strategies focus on disassembling for reuse and recycling, the last focuses on the efficiency of recycling operations.

6.1 Design for Disassembly

The ability to effectively disassemble construction is paramount to circular architecture primarily for two reasons: it results in significant labour cost savings and reduces the contamination of materials for recycling. That being said, many separation problems could be avoided by improvements at the design change (Barton, 1979).

Design for physical separation in lieu of chemical separation is a simple way of making recycling more economical (Barton, 1979). For example, in choosing a curtainwall system, dry-glazed are preferable to wet glazed systems since they use gaskets rather than sealants (Canada Mortgage and Housing Corporation, 2004), which are difficult and costly to detach from recyclable components during disassembly (Barton, 1979).

The simplicity of an assembly is also conducive optimizing disassembly and sorting (Durmisevic, 2010), which are significant recycling cost factors (Ashby, 2013). For example, one could opt for a face sealed barrier system, which has relatively elementary componentry compared to water-managed or pressure-equalized systems (Canada Mortgage and Housing Corporation, 2004). Considering the reduced lifespan of circular enclosures, simple options such as face-sealed curtainwalls, which are often overlooked for their lack of long-term durability (National Institute of Building Sciences, 2016), become viable options.

6.2 Prefabrication

In his book, Berge suggests that there is a great amount of material and cost savings that can be achieved in prefabricating assemblies (Berge, 2009). Particularly in a circular curtainwall, where there is an implied hierarchical equality between assembly and disassembly (Durmisevic, 2010), manufacturing in a controlled environment reduces waste that is inherent to construction and demolition sites, and maximizes the quantity of recyclable material (Memari, 2013). In addition, assuming the same entity is responsible for assembly and disassembly, the identification and sorting of components is streamlined. Choosing a unitized system, for example, rather than stick-built, makes maximum use of prefabrication.

6.3 Redundant Recycling Processes

The efficiency of recycling processes, which is consistently identified as a critical factor in making recycling economically viable (Barton, 1979; Berge, 2009; Ashby, 2013; Durmisevic, 2010), is a leading cause for why many materials that are potentially recyclable are condemned to landfill (Berge, 2009). As order and concentration of material are fundamental to efficient recycling (Barton, 1979), one can, by maximizing the redundancy of materials, reduce the number of recycling processes necessary and reduce sorting, both of which are great cost-saving measures (Barton, 1979). Polymers in particular, which are used in several curtainwall components (Canada Mortgage and Housing Corporation, 2004), present major problems in waste management in part because they have similar physical properties and no electrical or magnetic properties for sorting purposes (Ashby, 2013). By using similar polymers for different components throughout the curtainwall assembly, both the order and concentration of materials could be improved.

7 Optimizing Curtainwall Components

The optimization of waste management for individual curtainwall components relies on what Durmisevic refers to as the “theory of levels” (2010, p.95), namely the lifespan classification of similarly durable components in the context of the lifespan of the building. Once this information is understood within the context of the assembly, designers can recalibrate the life expectancy and waste management of components.

7.1 Optimal Material Selection Based on Recycling Efficiency

The use of materials because of their durability (National Institute of Building Sciences, 2016), despite the fact that they are non-reusable and non-recyclable is common in curtainwalls. However, adhering to Durmisevic’s theory of levels (Durmisevic, 2010), the reduced timeframe of a circular curtainwall allows the use of materials that are perhaps inferior in terms of durability, but superior in terms of waste management. Thus, materials that are difficult, expensive or impossible to recycle can be substituted for reusable or economically recyclable ones.

7.2 Design for Disassembly

While Barton focuses largely on design for disassembly of assemblies, Berge discusses principles aimed at individual components. As recycling feasibility relies on material purity (Berge, 2009), it is important that recyclable materials are manufactured in such way that their ability to be recycled is not compromised. Berge discusses the use of “standardized monomaterials” (Berge, 2009, p. 16), that is to say of a homogenous nature, such as a sheet of glass. He points out that typically the use of monomaterials is neglected in favour of multimaterial components, particularly where cladding insulation and structure are integrated. He uses the example of laminated glass, where both glass and interlayer could be recycled, but once laminated together are condemned to landfill (Berge, 2009). In such cases, one could attempt to divide multimaterial components into monomaterials. Here, as in with material substitution, designers should strive to obtain a similar level of performance as the original, with the option of sacrificing durability. For example, laminated glass with thermal or acoustic interlayer could be substituted for regular glass with an acoustical or thermal film, which can eventually be removed rather than being permanently laminated.

7.3 Preservation

Another way of reducing material waste is simply to extend the serviceable life of a component (Ashby, 2013). This strategy could either be used once the feasibility of recycling has been ruled out, or where components are at little risk of being damaged during disassembly and reassembly. Ideally, components are preserved without increasing the difficulty of eventual disposal (Barton, 1979).

Factors that affect the serviceable life of building enclosure components to be taken into consideration include: the physical and chemical properties of the material itself; the local environment and its climatic conditions; construction and execution; and maintenance (Berge, 2009). The concept of preservation generally follows mainstream principles of typical curtainwall detailing. This can be accomplished at detail level, for example as the proper use of setting blocks contributes to the preservation of glazing units (Canada Mortgage and Housing Corporation, 2004). It can also be done, during construction when materials are vulnerable to additional stresses (Berge, 2009). The prefabrication of elements can further contribute to maximising the durability of components. For example, opting for a unitized curtainwall typically increases the durability of components, and of the overall assembly by maximizing quality control and limiting exposure to elements (Canada Mortgage and Housing Corporation, 2004).

8 Conclusions

In his description of refurbishment, Ashby (2013) gives the example of an axe that over the course of its life gets two new heads and three new handles, but always remains an excellent axe. When we strive to apply this mode of thinking to curtainwall assemblies, and integrate regular refurbishment into the design life of a product, we not only give it an essentially infinite lifespan, but we also introduce the possibility of ecological endeavours that are not feasible when the serviceable lifespan of the product is only as strong as its proverbial weakest link.

The principles of circular architecture are not without their challenges, particularly those related to the economic implications of recycling. However, many strategies allow us to accommodate the shortcomings of our current recycling infrastructure to develop circular models that are both economical and sustainable. The shorter lifespan of a single application of a circular curtainwall gives an added flexibility that allows designers to effectively optimize waste management strategies. This allows the refurbishment of degraded curtainwall components, and obsolete curtainwall technology, which ultimately means that each application is potentially superior to its predecessor. There is also the advantage, in a situation where assembly and disassembly are given equal hierarchical roles in a product’s life cycle, that all steps of recycling operations, including disassembly and sorting, are optimizable.

By playing into these advantages, strategies can be developed at different scales of application to optimize waste management for circular curtainwalls. At the industry level, this means reinforcing regulations on waste management in order to improve recycling infrastructure, and consequently the economy, breadth, and accessibility of recycling operations. At the assembly level, strategies such as design for disassembly, prefabrication and material redundancy reduce costs related to labour and recycling processes in order to render disassembly and waste management more timely and cost-effective. At the component level, strategic manipulation of lifespan and waste management of individual parts results in a comprehensive life-cycle optimization. Though some of these strategies may be in opposition to one another, particularly between scales of application, it is up to designers to be critical in choosing waste management optimization strategies that appertain to their particular design challenges.

The reader should note that the strategies outlined in this paper pertain exclusively to the optimization of waste management. While waste management is a critical part of the overall sustainability of a curtainwall assembly, there are many other factors that are extremely important to consider. Factors including the energy performance of the assembly, and the embodied energy of its componentry can and should be used in parallel with waste management optimization strategies to develop comprehensively sustainable enclosures.

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