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“Depending on your viewpoint, concrete can either be considered a hero or villain of modern civilization.”

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Americas

The Midwest’s biggest city has continued to rally as COVID-19 restrictions subside, bolstering the drive for new projects to progress and launch. On Chicago’s Goose Island, a Canadian developer has unveiled plans to bring up to 2,650 apartments to the area, which is light on residential dwellings. The proposed five-tower Halsted Point could feature buildings up to 178 meters tall. Over in the city’s bustling Fulton Market district, a Chicago-based developer has proposed a 19-story life sciences lab building at 400 North Elizabeth Street. Also in the West Loop, BMO Tower, a 1.5 million-square-foot (139,354-square-meter) office high-rise has topped out. The 222-meter-tower will feature ceiling spans upwards of 12 feet (3.7 meters) and private terraces on some of the levels. In the same neighborhood, a 47-story mixed-use tower, 640 West Washington Boulevard, is moving forward after approval from the Chicago City Council. The development will endeavor to reduce its resource usage through energy-efficiency measures, reduced water usage, provision of EV charging stations, and a green roof.

Over in Wisconsin, high-rise activity continues to be strong. In Madison, Baker’s Place, a proposed 15-story residential timber building would incorporate an existing two-story historic building at the site’s corner. In Milwaukee, lakefront development Couture has begun construction. Planned to reach completion in late 2023, the project will deliver 322 residential units and 3,980 square meters (42,837 square feet) of retail space. Also in Milwaukee, a 32-story residential high-rise received conceptual approval by the Historic Third Ward Architectural Review Board. The board approved the 111-meter-tall 333 North Water Street after evaluating its height, mass, and concept.

In Toronto, a triple-building complex has been proposed on a site that has been vacant for years. The three residential buildings at 1467 Bathurst are planned to each reach 30 stories in height. In the city’s downtown core, a massive nine-building master plan has been proposed to deliver 3,500 homes and an elevated park. The mixed-use ORCA Project would also add retail, entertainment, and affordable housing to the area. In the Toronto suburb of Whitchurch-Stouffville, a 16-story high-rise has been approved, after amendments trimmed it from 18 stories following a public meeting. Elsewhere in Canada, two residential projects are taking shape in Vancouver and Montreal. One, 1698 West Georgia Street, a 33-story tall tower with multiple green roofs and a two-story waterfall, is inspired by the rugged rock formations of a nearby mountain range. The other is the Imperia Condominiums, which are set to reach 22 stories with studios and one-bedrooms. Commercial space will occupy the podium.

New renderings have been released of Project Commodore, a planned mixed-use supertall set to reach 85 stories and 453 meters in New York City. The massive structure is set to contain 500 hotel rooms spanning 453,000 square feet (42,085 square meters); 10,000 square feet (929 square meters) of retail space, a new elevated, publicly accessible plaza space overlooking the surrounding Midtown neighborhood; and 2.1 million square feet (195,096 square meters) of office space. Just a few blocks away, Summit One Vanderbilt, a four-story
Sustainable Tall Building Design Exemplars

Abstract

Some 97 cities worldwide, including most of the world’s megacities with a population of 10 million or more, have signed onto the C40 Cities Climate Pledge goal of achieving net-zero carbon emissions by 2030. As this date edges closer, this paper steps back to assess some of the best-in-class tall buildings that stand as exemplars, representing the progress that has been made, as well as the challenges that still lie before us. Recognizing that the building industry itself will be a critical component, while certainly not the only factor, in cities realizing these goals, it is incumbent upon the developers, designers, and constructors of tall buildings to comprehend what is possible, and advocate for the best practices represented by these projects, both within their industry and in the communities where they build.

Keywords: Carbon Emissions, Embodied Energy, Net-Zero, Operational Energy

Introduction

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations (UN) body responsible for assessing data and science relating to climate change. In 2015, at the UN Framework Convention on Climate Change (UNFCCC), the IPCC was tasked with examining the impact of global warming and the pathways to reduce greenhouse gas (GHG) emissions. In 2018, the IPCC Special Report: Global Warming of 1.5°C was published, which presented a blunt outlook for the future: “Without increased and urgent mitigation ambition in the coming years, leading to a sharp decline in greenhouse gas emissions by 2030, global warming will surpass [an average increase in temperatures of 1.5 degrees Celsius (°C) above pre-industrial levels] in the following decades, leading to irreversible loss of the most fragile ecosystems, and crisis after crisis for the most vulnerable people and societies” (IPCC 2018).

While an increase in 1.5°C may not seem significant, if overall global warming reaches 2.0°C the world will be confronted with considerably more stark results. In a climate risk assessment, the IPCC indicates that global food security, water resources, and exposure to drought, heat, and coastal submergence transition from “moderate” to “high” risk when temperatures rise between 1.5°C and 2.0°C on average (IPCC 2018). This research reinforced the goals of the UN Paris Agreement of 2015, which is a legally-binding, international treaty for participating nations to limit global warming to well below 2.0°C, and preferably to 1.5°C, compared to pre-industrial levels (UN 2015). With increasing populations, in order to avoid surpassing the 1.5°C, significant innovations and improvements must be made to limit greenhouse gas emissions.

As part of this agreement, countries must transparently report all climate change mitigation efforts and progress in achieving the same. This has seen efforts from international Green Building Councils (GBCs) to create strategies to reduce emissions released from the building industry, with the eventual goal to have all new construction be net-zero. In other words, for any quantity of greenhouse gas emissions released into the atmosphere by the construction or operation of a building, the equivalent amount is also removed as an outcome of its design.

The Impact of Tall Buildings

According to the UN Environmental Committee, “the buildings and construction sector should be a primary target for GHG emissions mitigation efforts.”
The Zero-Carbon Hybrid Future of Tall Timber

Abstract
A patent-pending Hybrid Timber Floor System (HTFS), with a prefabricated composite floor panel, offers significant advantages over traditional building technology. It is capable of clear floor spans of up to 12 meters; reduced structural floor thickness; higher and more consistent quality; reduced construction time; greater occupant safety; more exposed wood; and superior sustainability attributes. The HTFS is the starting point for a supertall zero-carbon hybrid timber building prototype design, with a concrete core and diagrid steel external structure. The prototype leverages energy efficiency, smart technologies, façade-integrated photovoltaics (PV), and a district energy cogeneration plant combined with an algae bioreactor, to achieve zero operational carbon on-site. Excess energy is provided to the surrounding neighborhood in a “net(work)-zero” carbon strategy, and a vision for future zero-carbon embodied energy is also outlined. This supertall prototype is a response to the oft-posed question: Can this type of construction ever be truly sustainable?

Keywords: High-Rise, Hybrid Construction, Mass Timber

Introduction
The Hybrid Timber Tower (HTT) prototype for Toronto, outlined in this paper, demonstrates that supertall buildings can be a catalyst for a dense, decarbonized future (see figures 1 and 2). Designed with a new patent-pending Hybrid Timber Floor System (HTFS), this prototype suggests that, while “zero-carbon supertall” buildings are already very much within the realm of the possible, the pursuit of all-timber “purity” is best abandoned if we want to meet our climate commitments.

The challenge to building tall with timber is inherent to the material itself: we are asking wood to do things it was not designed to do. Wood becomes a more inefficient structural material at greater heights, which is why hybrid solutions are more common in taller buildings. Further, tall all-wood mass timber structures require an uneconomical volume of wood to replicate the structural capacities of steel and concrete; this limits its use in tall buildings. Wood suffers from much greater shrinkage and creep than steel and concrete, which makes its use as vertical structure in combination with concrete cores and aluminum curtain wall systems very problematic. Engineered wood products are currently not able to achieve the necessary

Figure 1. Street view of Hybrid Timber Tower, Toronto, looking north at dusk. This supertall zero-carbon hybrid timber building prototype is designed with a concrete core and diagrid steel external structure, and leverages energy efficiency, smart technologies, façade-integrated photovoltaics (PV), and a district energy cogeneration plant, combined with an algae bioreactor, to achieve zero operational carbon on-site.
Is a Zero-Carbon Concrete Skyscraper Possible?

Abstract

Tall buildings can provide many positive environmental contributions, concentrating large populations into efficiently operating systems, sharing resources among many users, and reducing transport and land occupancy, to name a few. But their sheer scale and the required investment of resources makes their carbon footprint too large to ignore. The structure of a tall building alone contains embodied carbon equivalent to between 15 and 30 years of operational carbon footprint. This figure increases with height. We can continue to use concrete to build tall, but we have to be much smarter about the materials we use. Already, our business-as-usual targets of cement replacement can reduce this embodied structural footprint by between 20 and 40 percent. But what if we targets 100 percent? This paper reveals some of the current and emerging developments in the field of low-carbon concrete, and will discuss the potential pathways for their adoption in tall buildings of the future.

Keywords: Carbon, Concrete, High-Rise, Sustainability

Concrete Past: Hero or Villain?

Depending on your viewpoint, concrete can either be considered a hero or villain of modern civilization (see Figure 1):

Hero

Concrete has been helping mankind flourish for thousands of years. Since its adoption by the ancient Greeks and Romans, concrete has grown to become our most popular and versatile construction material. It forms our infrastructure, our homes, our workplaces, and of course, our tall buildings. Until now, the use of Portland cement-based concrete has only been limited by our ability to understand and design it.

Villain

It may not capture much public attention as a hidden and "hard-to-decarbonize" sector, but concrete production is estimated as being responsible for 7 to 10 percent of total global carbon emissions (BZE 2017, Siegel 2020). This is more than all the cars in the world combined. This issue is particularly relevant for tall buildings, in which the concrete intensity is high, and its use virtually unavoidable. It is estimated that the structure of a tall building contains embodied carbon on the order of 500 to 700 kilograms of CO₂ per square meter of gross floor area (GFA); which, compared with efficient operational emissions of 20 to 40 kilograms CO₂ per square meter of GFA per year, is equivalent to 15 to 30 years of building operations. Increasing height only exacerbates this figure (Gan et al. 2017) (see Figure 2).

Concrete Composition

To be clear, concrete and cement are two different, but interlinked things. Cement is a fairly standard and unchanging ingredient, although alternatives do exist. Concrete, on the other hand, has many different variations on its recipe or mix design, which influences characteristics like the strength, workability, shrinkage, and even the color of the concrete (see Figure 3).

Carbon Sources

Although cement only makes up 8 to 15 percent of the weight of concrete, it contributes a staggering 85 to 95 percent of the CO₂ emissions (Kestner 2020). Much of this can be attributed to cement production. Virtually all modern cement in construction is ordinary Portland cement or a variation of it, which is created by heating limestone and clay at approximately 1,450 degrees Celsius,
Towards the Carbon-Neutral High-Rise: The Role of Embodied Carbon

Abstract
The built environment sector is responsible for some 39 percent of global carbon emissions. Therefore, decarbonizing the building industry is one of the most effective and important actions on the climate change-mitigation agenda. High-rise buildings produce carbon emissions throughout their life cycles. Traditionally, attention has mainly been given to their operational carbon footprint. However, embodied carbon of built assets contributes to around 11 percent of global carbon emissions, and will be responsible for approximately 50 percent of the entire carbon footprint of new construction between now and 2050.

This paper presents a case study on how the optimization of various structural concrete elements of towers could contribute towards significant carbon savings. For example, by optimizing the design of core walls, slabs, and raft foundations, the authors have managed to achieve a carbon reduction equivalent to the emissions that would result from 78 million kilometers (14 million kgCO$_2$e) of travel in an average gasoline-powered car. The paper then summarizes a set of tangible savings made via various design optimization techniques.

Keywords: Carbon Neutrality, Embodied Carbon, Skyscraper, Sustainability

The Climate Emergency
Greenhouse gas (GHG) emissions have risen at a rate of 1.5 percent per year in the last decade, stabilizing only briefly between 2014 and 2016. The total GHG emissions reached a record high of 55.3 gigatons of carbon-dioxide equivalent (GtCO$_2$e) in 2018. Implementing the current policies, GHG emissions are estimated to reach 60 GtCO$_2$e by 2030. However, to meet the Paris Agreement goals for 2030, the current emissions must be lowered by 30 GtCO$_2$e, and only then will global warming be limited to less than 1.5°C (UNEP 2019). The damage from climate change will be widespread, and sometimes surprising. It will go far beyond drought, melting ice sheets, and causing crop failures. The risks that weather and climate pose to human life are not always as specific to the peculiar circumstances of time and place—consider the sudden and global onset of the COVID-19 epidemic (Declan 2020). Figure 1 (Houghton et al. 2001) shows the increases in both the mean, and the variability of climate events, which affects the probability of hot and cold extremes, leading to more frequent hot events with more extreme high temperatures, and fewer cold events.

Lessons learned from the COVID-19 pandemic show that we cannot ignore the warnings that are repeatedly issued by the scientific community and be caught unprepared for another natural disaster. Currently, there is a strong consensus amongst scientists that climate change will be the next global crisis that we will face.

Figure 1. Extreme climate events are likely to increase, both in terms of probability and severity, if the planet continues to warm at current rates. Source: Houghton et al. 2001
Tall Buildings And Life Cycle Approaches: A Debate That Must Be Started

Abstract
By means of life cycle assessment (LCA) and life cycle costing (LCC) analyses, the authors assess the environmental and economic impact occurring during the life cycle of different tall building structures in three macro-categories: all-concrete, all-steel and concrete-steel composite. The study focused on three areas in Asia-Pacific: Bangkok and Singapore, markets with more recent experience of tall buildings, and Sydney, where the market is mature. The research seeks to identify which could be the most advantageous comprehensive structural solution, in terms of both sustainability and cost. The research project is organized into two stages: the first stage, now completed and presented in this paper, focuses only on the construction phase; the second will consider the use and end-of-life phases of the building scenarios.

Keywords: Life Cycle Assessment, Life Cycle Costing, Tall Building

Background
To provide a unique and linear definition of “sustainability” is difficult, but the basic principle was stated at the Brundtland Conference in 1987: “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland Commission 1987). Over time, a graphic representation of this concept has been developed, showing three recognized pillars of sustainability: economic, environmental, and social (see Figure 1).

Although the social sphere plays an important role, in the construction sector, economic factors have always had a greater influence on design decisions; however, in recent years, the environmental impetus has begun to take a major role.

Among the numerous tools that have been developed to achieve these objectives, the life cycle analysis (LCA) has been chosen for the specific aim of the research that will be presented in this paper. It provides a useful and standardized evaluation method that can be applied at the different stages of a design process to evaluate different alternatives, depending on what is being considered: environmental impact, costing, and so on. The basic concept is to adopt “a systematic approach to environmental management” that can “create options for contributing to...
About the Council

The Council on Tall Buildings and Urban Habitat (CTBUH) is the world’s leading non-profit organization for all those interested in the future of cities. It explores how increased urban density and vertical growth can support more sustainable and healthy cities, especially in the face of mass urbanization and the increasing effects of climate change worldwide.

Founded in the USA in 1969, the CTBUH member network embraces more than a million professionals working in all building industry sectors in almost all countries of the world. With offices in Chicago, Shanghai, and Venice, the Council runs hundreds of multidisciplinary programs across the world each year, through its regional chapters and expert committees, its annual conferences and global awards program, through funded research projects and academic collaborations, and via its extensive online resources and physical outputs. The Council is perhaps best-known to the public as the arbiter of tall building height and the global authority that bestows titles such as “The World’s Tallest Building.” Operating on a global scale, CTBUH serves as a platform for both cutting-edge information-share and business networking for all companies and professionals focused on the inception, design, construction, and operation of cities, and the buildings they comprise.

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