

Supporting efficient, safe and affordable modular construction practices through standards

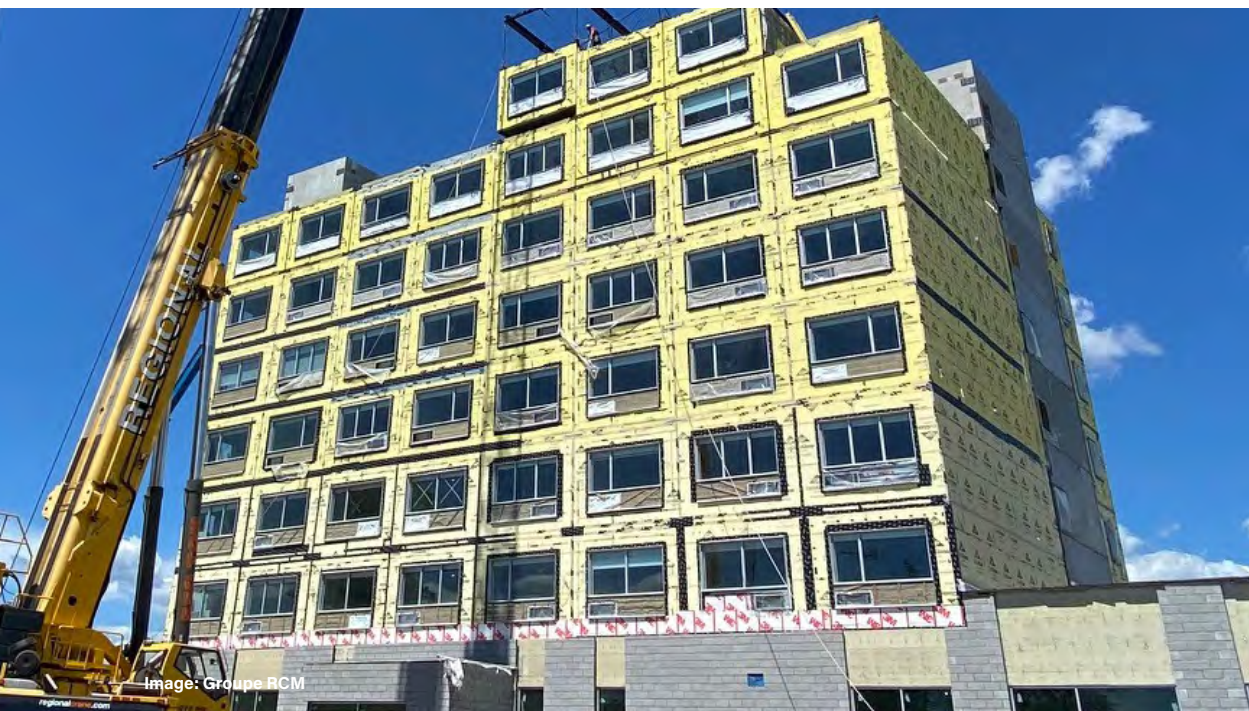


Image: Groupe RCM

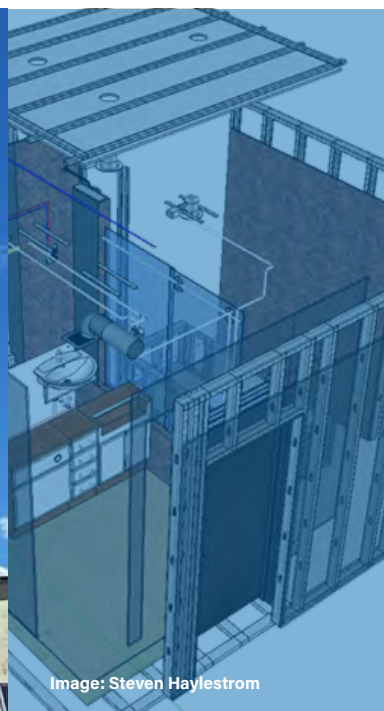


Image: Steven Haylestrom

Though the average person may not necessarily consider their impact, building codes and related standards are essential to Canadian life. They are carefully developed by technical experts working by consensus to set requirements that help ensure the health, safety, and comfort of building occupants while considering advancements in technology. Volumetric modular buildings are an example of construction innovation. In September 2021, CSA Group published CSA Z250, *Process for delivery of volumetric modular buildings*. This standard supports volumetric modular buildings by helping to meet the requirements of the building code in each jurisdiction.

Table of Contents

What is a volumetric modular building?	3
Why modular construction?	3
Modular construction in Canada	4
What building codes apply to modular buildings?	5
How CSA standards can help the industry progress	6
The role of standards in building safety, quality, and efficiency	7
Case Study 1: Built Prefab	7
Case Study 2: NRB Modular	9
Case Study 3: Groupe RCM (RCM Group)	11
How modular construction can support housing supply	12
Conclusion	12
References	13

What is a volumetric modular building?

A *volumetric modular building* is defined as a building that has been constructed in a factory to 70%-90% completion, depending on the design. Parts of the building that can be easily transported are built in a factory and then taken by boat, train, transport truck, or even flown to the building site for the final stages of assembly.



Why modular construction?

Since volumetric modular construction moves a high percentage of the construction of a building from the construction site to a factory, it offers numerous advantages over more conventional methods of construction. For example, the climate-controlled factory environment permits construction regardless of inclement weather conditions. The factory environment can be safer for workers and provide easier access to materials, equipment, PPE, and facilities. Modular construction can also reduce the noise and pollution at the construction site while minimizing disruption by limiting the number of deliveries and labourers.



A common technique in modular factories is to construct modules using a panelized system with prefabricated floor, walls, and roof panels that are then attached to assemble each module in a highly systematic fashion.

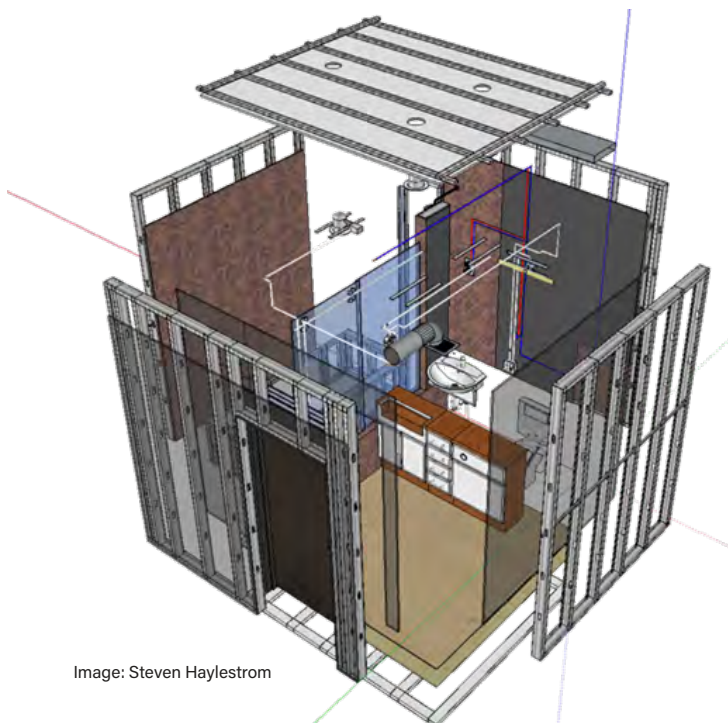


Image: Steven Haylestrom

Volumetric modular unit

This illustration shows one "pod," "module," or "unit." Many similar or identical modules are built in a factory and transported to the building site, where they are assembled using specific modular industry techniques. This final construction step may include lifting modules to stack them, sealing intermodule connections, and completing finishes on the exterior and interior of the building.

Modular buildings can be any size, from a home consisting of a single module, to the world's tallest modular building (the Clement Canopy skyscraper in Singapore) consisting of 1,899 modules.

Modular construction practices as compared to conventional building methods

Potential Benefits

- Accelerated building schedule/shorter construction time
- Increased worker safety
- Environmentally friendly practices



Potential Challenges

- Larger upfront equity required
- Larger planning hurdles due to the need for design for manufacture and assembly (DFMA)
- Logistics challenges with modules' delivery



Another advantage of modular construction occurs during the planning and design phase. Architects, engineers, and other professionals design for in-factory construction by specifying both materials and processes that increase a building's quality, reduce material waste, decrease labour, and increase productivity. This, in turn, allows for an assembly-line style of construction that uses the latest technology in advanced manufacturing, such as ceiling-mounted overhead craning systems and computer numerical control (CNC) cutting machines. These innovative processes can improve quality by minimizing manual or repetitive tasks. Overhead craning and automated systems can also significantly reduce a labourer's time spent working at heights, reducing the risk of injury.

Modular construction in Canada

Although modular construction is being used with great success in Sweden, Singapore, and many other countries, this building method has not been common in North America. In fact, modular construction makes up only around 4% of all new building construction in Canada. Several reports have indicated advancing this method in Canada requires guidance and education in modular construction. Since designers, manufacturers, and developers may not be as familiar with the roles and responsibilities of regulators in different jurisdictions, it can create roadblocks that slow approvals and duplicate in-factory and on-site inspections [1]. Thus, additional education for stakeholders in this method, including applicable building codes and standards, could help reduce roadblocks and increase the use of modular construction in Canada.

What building codes apply to modular buildings?

Modular buildings in Canada must meet the same building codes and bylaws as conventionally constructed buildings that are applicable in the building's final location. The primary difference in modular construction is not the building codes and regulations they must meet; rather, it is process used to achieve the objectives of the code. In modular buildings, some components, such as electrical, plumbing, or HVAC systems, are encased in the finished product during the factory-built process. As a result, when the module arrives on site, it may not be possible for the building inspectors to look at the work and confirm it meets building code requirements.

The Standard CSA A277:16 (R2021), *Procedure for certification of prefabricated buildings, modules, and panels*, is designed to help modular buildings meet building code requirements during a building's in-factory construction phase. This includes the use of a third-party inspection agency accredited by the Standards Council of Canada (SCC) that can certify the modular products leaving a factory conform to CSA A277. An accredited inspection agency's job is to review drawings and plans, conduct in-factory inspections, and approve modules during different construction phases. This involves reviewing all building components – including structural, mechanical, electrical, gas, and plumbing – to ensure all applicable Codes and Standards are met. It also includes inspecting in-factory built portions of the building during its modular construction phase. These in-factory inspections can eliminate further inspections of the modules when they arrive at the final building site. The off-site (in-factory) inspection is a crucial step, otherwise, the walls, floors, ceilings, or other parts of the module would likely need to be removed from already-finished portions of the building for on-site inspection.



Image: Steven Haylestrom

The photo above shows a module with a higher degree of exterior finish being lifted by a crane off a transport truck.

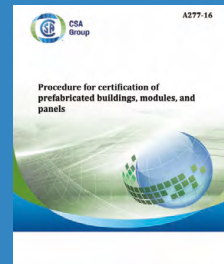


Image: Steven Haylestrom

The interior of modules can be finished to varying degree. In fact, many modules include fixtures and equipment, such as sinks, heaters, and appliances already connected to gas, electrical, and plumbing systems. Modules can even contain furniture and other finishing touches, such as window treatments.

A277 facilitates bringing modular construction within the scope of the building code in a more organized fashion, along with the new CSA Z250 Standard, which grants the opportunity to augment this process by including more aspects of the overall construction process.

—Paul Chang, Provincial Building Administrator, Municipal Affairs, Government of Alberta



How CSA standards can help the industry progress

Certification of a module to CSA A277 in a factory is evidence that its design and construction should comply with the applicable building codes at the final installation location. Compliance with CSA A277 is mandatory only if the legislation of the jurisdiction where the building is being erected requires it. CSA A277 has been successfully incorporated by reference as part of the building code in Alberta (National Building Code – 2019 Alberta Edition), Ontario (Ontario Building Code), and Quebec (Code de Construction [Quebec Construction Code] and the Code de Sécurité du Québec [Quebec Safety Code]). Proof of code compliance prior to delivery for modules with their final setting in Alberta, Ontario, and Quebec removes the need to further inspect or approve modules on-site. This greatly facilitates and streamlines construction by expediting on-site approvals processes.

In other provinces and territories, CSA A277 is not directly referenced in the building code. This means the authority having jurisdiction (AHJ) responsible for building inspection processes may need to inspect the module on-site to be in compliance with applicable legislation and regulations in that jurisdiction.

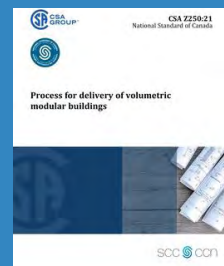
While the procedures detailed in CSA A277 often help in-factory constructed components of modular buildings meet building code and other jurisdictional requirements, prior research identified a need for an additional standard to address other parts of the modular construction process—such as module design and delivery [2]. As a result, the standard CSA Z250:21, *Process for delivery of volumetric modular buildings*, was developed to complement CSA A277 by providing further guidance on modular construction. The development of the new standard involved a thorough review of the entire process, with input from key stakeholders and industry experts.

CSA Group standards for modular construction

CSA A277-16 (R2021) <i>Procedure for certification of prefabricated buildings, modules, and panels</i>	CSA Z250:21 <i>Process for delivery of volumetric modular buildings</i>
Focuses on the in-factory portion of construction	Focuses on the processes and procedures before and after the in-factory portion of construction, with reference to CSA A277 for in-factory procedures
<ul style="list-style-type: none"> ▪ Certification of a factory’s quality program ▪ Certification of prefabricated products ▪ Auditing a factory’s quality program ▪ In-factory inspections of prefabricated products 	<ul style="list-style-type: none"> ▪ Design ▪ Quality control in modular manufacturing ▪ Approvals ▪ Logistics, transportation, and storage ▪ Non-modular and modular sitework ▪ Module lifting, placement, and setting ▪ Installation and finishing ▪ Commissioning and handover
<p>Both Standards require that all design, construction, inspections, testing, transportation, and other processes involved comply with the technical and administrative regulations applicable at the building’s location.</p>	

CSA Z250 has brought enormous clarity to our day-to-day operations at Z Modular and reliability to our design and approval processes at Skyhook Architecture. It offers comprehensive guidance that sets the foundations for quality and innovation in our rapidly evolving industry.

—David Warne, OAA, Principal Architect, Skyhook Architecture; VP of Design, Z Modular



The role of standards in building safety, quality, and efficiency

The following three case studies explore how CSA Z250 and CSA A277 can help facilitate modular construction projects by streamlining processes and procedures. At the same time, these Standards can contribute to ensuring each construction phase is uniformly documented, controlled, and executed so as to put the public interest first.

Case Study 1: Built Prefab

The British Columbia-based company, Built Prefab, constructs a line of nine modular single-family homes. The Built Prefab homes range in size from 56.5 m² (608 ft²) to 184.3 m² (1984 ft²) and are constructed using 1 to 3 modules of various sizes. Every module is certified as meeting CSA A277 requirements.

The estimated time to obtain one of Built Prefab's single-family homes, from design to handover, is between 25 weeks (about 6 months) and 90 weeks (about 1 year and 7 months). One reason for discrepancies in delivery time is, notably, the permitting process in different jurisdictions, which can take anywhere from 2 weeks to 12+ months to be completed, according to Built Prefab¹.

By following a repeatable design, modular companies have established solutions for transportation and lifting procedures, including "pick-points," (i.e., the locations where modules are hooked to and lifted by cranes), and on-site assembly, identifying where modules should be connected (or "stitched") together at their "intermodular connections." The CSA Z250 Standard provides important requirements in developing plans for the safe transportation, lifting, and installation of modules on-site.

Since these steps are common for modular buildings, having nationally-recognized standards can help ensure the permitting and construction processes are more uniform, controlled, and manageable by stakeholders, including on-site and third-party inspection officials, developers, on-site constructors, manufacturers, and designers.



The "Shore" is one of nine current modern modular homes offered by Built Prefab's 2021 catalogue. Further customization options mean no two dwellings need to be alike.

Using pre-designed factory procedures, processes, and materials in building designs shortens construction time. The use of industry standards can further improve the efficiency, affordability, and code-compliance of these housing solutions.



The "Forest" model modular home from Built Prefab consists of two modules, built to approximately 90% completion in-factory.

These modules, which are 4.88 m by 11.58 m (16 ft. by 38 ft.) and 4.88 m by 16.45 m (16 ft. by 53 ft.), are constructed in a factory, then transported by flatbed truck, craned into place, and "stitched" together to make them air and weather-tight on-site.

¹ Permitting times for construction vary by location.

Notably, the delay in permitting processes has been widely cited by stakeholders as one of the major barriers to the success of modular construction in Canada [1]. In some cases, stakeholders with experience in both conventional and modular construction have reported that modular construction permits can take up to six times longer than conventional build permits. This is, in part, attributable to a lack of guidance and understanding of modular building processes.

However, Standards such as CSA A277 and CSA Z250 can help regulatory officials become more familiar with modular construction approvals processes and procedures. Officials can spend less time doing independent research to issue approvals, which can result in a faster permitting process. In fact, faster modular building permit approvals are common in provinces that reference CSA A277 in their legislation and/or rely consistently on it, including British Columbia, Alberta, and Quebec.

CSA Group standards for modular construction: Comparison of requirements

CSA A277-16 (R2021) <i>Procedure for certification of prefabricated buildings, modules, and panels</i>	CSA Z250:21 <i>Process for delivery of volumetric modular buildings</i>
Focuses on the in-factory portion of construction	Focuses on the processes and procedures before and after the in-factory portion of construction, with reference to CSA A277 for in-factory procedures
<ul style="list-style-type: none"> ▪ Drawing inspections ▪ Calculation inspections ▪ Structural inspections and testing ▪ Plumbing inspections and testing ▪ Heating inspections and testing ▪ Electrical inspections and testing ▪ Gas inspections and testing ▪ Random factory audits and inspections 	<ul style="list-style-type: none"> ▪ Safety plan ▪ Tolerance management plan ▪ Plan for the protection of modules for transport and storage ▪ Transport routing plan and site traffic control plan ▪ Delivery and offloading plans ▪ Inspections of modules before, during and after storage, and after delivery ▪ Module repair plan ▪ Temporary weatherproofing plan ▪ Lifting plan and procedure ▪ Placement and setting plan ▪ Utilities and service coordination plan ▪ Commissioning plan

The above lists show some key aspects of modular building that are included in these standards. Both standards have documentation and planning requirements surrounding who conducts inspections, when, and how.

Case Study 2: NRB Modular

NRB Modular Solutions (part of the Dexterra Group) is one of the largest modular producers in Canada, with four manufacturing facilities in three Canadian provinces: Ontario, Alberta, and British Columbia. NRB Modular Solutions constructs buildings in various sizes and for various uses, including buildings for multi-family affordable and social housing.

This innovative company places significant emphasis on the importance of pre-construction phases in modular construction. Time invested into these phases contributes to successful outcomes in both scheduling and overall budget. Integral components of the planning process include early considerations for layout or “configuration” of modules, transportation regulations, size of the final product, and mechanical and electrical design components that need to be installed in the factory and then coordinated for completion on-site.

CSA A277 includes in-depth planning and organization requirements applicable to the work that takes place in-factory. These requirements are not only helpful for the quality and safety but also for the overall success of project. However, many modular companies attribute the success or failure of a project to various aspects covered in CSA Z250, including the need to clearly identify the roles and responsibilities for each task during every stage of a project.

For companies like NRB Modular Solutions that do the off-site and on-site work but hire others for the transportation, this organizational delineation is noted as an essential step. Even companies that do everything “in-house” and have departmental divisions make it imperative that teams work effectively together. A clear scope of work helps them outline the defined off-site and on-site work, scheduling, as well as documentation initiation and control.



Image: Steven Haylestrom



Image: NRB Modular Solutions

Built by NRB Modular Solutions, this temporary housing unit supports citizens at risk of homelessness. It took just under six months to construct, from contract to occupancy.

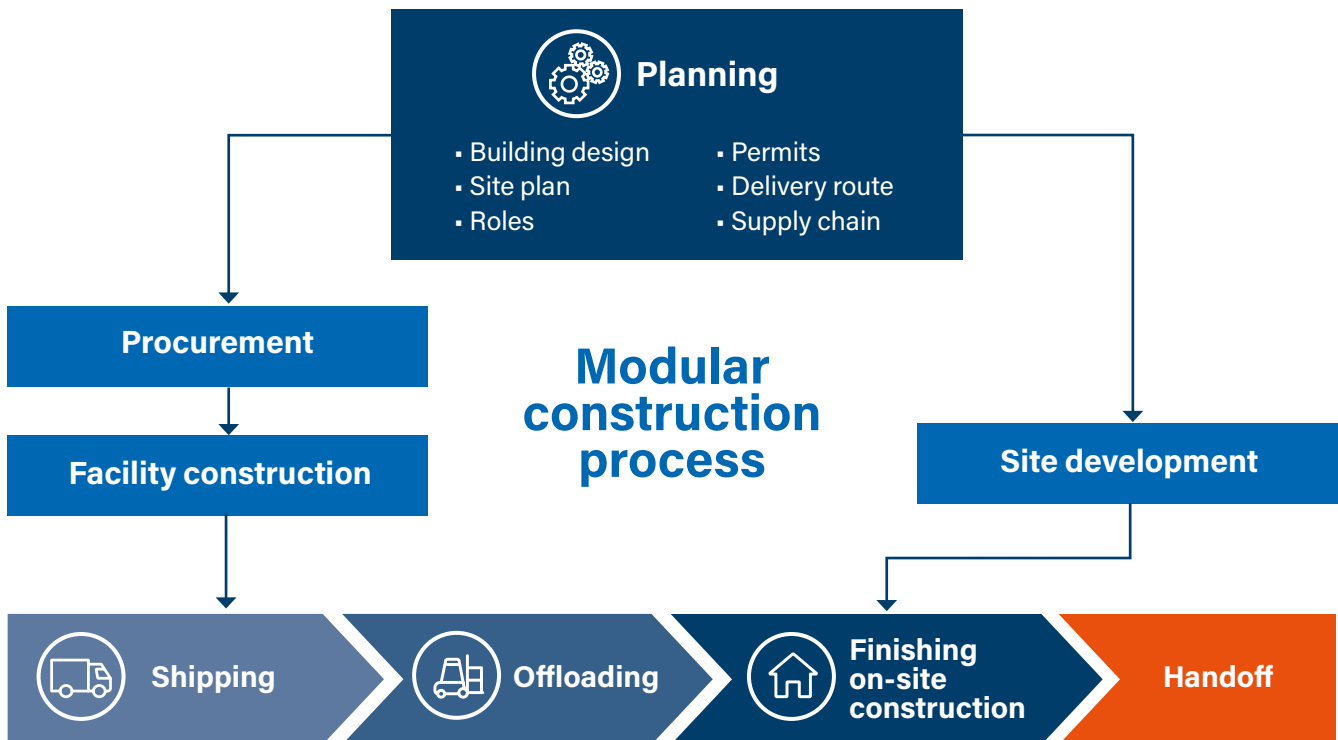


Built by NRB Modular, constructed using volumetric modular method, this building provides 100 affordable single-occupancy rental suites in Toronto, Ontario [2].

There are many different stages in a modular product even after a repeatable design drawing package is complete. CSA Z250 does not direct these stages but rather outlines important requirements for processes and procedures surrounding integral aspects of the stages, such as communication, planning, and documentation, to help regulate the multitude of modular building aspects.

This is particularly important because modular construction processes can be more complex than those for conventionally-built structures. Particularly of note is the addition of transportation regulations, as well as loading and offloading the modules. By their very nature, modular buildings involve a great collaborative effort to ensure all regulations are met or exceeded. CSA Z250 helps to ensure those efforts are consistent, effective, and safe.

Modular construction process



Case Study 3: Groupe RCM (RCM Group)

Groupe RCM, out of Quebec, Canada, constructs modular buildings for use as hotels, apartments, worker camps, retirement homes, student housing, and single-family residences. Currently producing 1486 m² (16,000 ft²) of living space per week, the company is expanding its production capacity by constructing a new plant to meet increasing consumer and market demands.

With such fast, efficient building processes, modular construction holds a lot of promise when it comes to addressing the lack of affordable housing in Canada. However, stakeholders expressed the importance of a regulatory framework that must help support this construction method. An essential aspect of both CSA A277 and CSA Z250 is the role of the certification bodies (or third-party inspectors) that carry out inspections and approvals.

How modular construction can support housing supply

According to the Canadian Mortgage and Housing Corporation (CMHC), housing is considered affordable when less than 30% of gross income is spent on adequate shelter, with shelter costs defined as rent or mortgage. Unfortunately, housing affordability in Canada has been on the decline for over two decades. Research from Oxford Economics found that, on average, "a home was 34% more expensive than a median-income household could afford." [3].



Image: Groupe RCM

This four-storey apartment complex has 136 rental suites. It was factory-built by Groupe RCM in 16 weeks, with 174 modules, all certified to CSA A277. On-site assembly took 20 weeks in total.



Image: Groupe RCM

This six-storey apartment complex with 76 rental suites was factory-built by Groupe RCM in 9 weeks, with 134 modules, all certified to CSA A277. On-site assembly took 7 weeks in total.



With such fast, efficient building processes, modular construction holds a lot of promise when it comes to addressing the lack of affordable housing in Canada.

Furthermore, by the account of the Office of the Parliamentary Budget Officer, the need for government-assisted housing will grow to encompass 1.8 million Canadian households [4] by the year 2025.

As of September 2021, CMHC ranked the degree of vulnerability of the Canadian housing market as having moved from moderate to high with evidence of the housing market overheating, meaning the housing demand is significantly higher than supply [5].

While many possible solutions to this issue have been proposed and examined, modular construction has been identified as a potential solution. In fact, to meet the housing affordability gap, in October 2020, the Government of Canada, through the Canadian Mortgage Housing Corporation (CMHC), launched the Rapid Housing Initiative (RHI). This initiative committed \$2.5 billion to the construction of modular, affordable housing and will support the rapid construction of over 10,000 modular housing units across Canada.

Conclusion

Modular construction is poised as one of Canada's key solutions to producing buildings that are safe, economical, and have key environmental attributes. While many modular construction companies have been innovating in this area, Canada still faces a number of challenges when it comes to affordable housing. The CSA A277 and CSA Z250 Standards are important tools to support modular construction. There is also an opportunity for additional education about the modular construction industry methods and standards [1].

As modular construction sees a major uptake in Canada's construction sector, CSA A277 and CSA Z250 can play an important role. This is an essential time to grow the knowledge base for modular construction methods and their associated regulations. Not only can these Standards help promote transparency, sustainability, and predictability to the public, they can also improve efficiencies and help deliver a quality product to clients. This can help increase confidence in modular construction and support a healthy economy and environment through innovation.

References

- [1] Canadian Standards Association (CSA), "Exploring the Existing Regulatory Framework for Modular Construction in Canada," July 2021. [Online]. Available: <https://www.csagroup.org/article/research/exploring-the-existing-regulatory-framework-for-modular-construction-in-canada/>
- [2] Canadian Standards Association (CSA), "High-Rise Modular Construction," Jun. 2020. [Online]. Available: <https://www.csagroup.org/article/research/high-rise-modular-construction/>
- [3] Oxford Economics, "Research Briefing, North America: Affordable housing will get increasingly harder to find," May 2021. [Online]. Available: <https://resources.oxfordeconomics.com/hubfs/Content%20Hub%20RBs/open20210518012500.pdf>
- [4] Office of the Parliamentary Budget Officer (Canadian Government), "Federal Program Spending on Housing Affordability in 2021," Aug. 2021.
- [5] Canadian Mortgage and Housing Corporation (CMHC), "Housing Market Assessment, Canada and Metropolitan Areas," Sept. 2021. [Online]. Available: <https://www.cmhc-schl.gc.ca/en/professionals/housing-markets-data-and-research/market-reports/housing-market/housing-market-assessment>

About CSA Group

CSA Group is a global organization dedicated to safety, social good and sustainability. We are a leader in Standards Development and in Testing, Inspection and Certification around the world including Canada, the U.S., Europe and Asia. Our mandate is to hold the future to a higher standard.

The mission of CSA Group's Standards Development organization is to enhance the lives of Canadians through the advancement of standards in the public and private sectors. We are a leader in standards research, development, education, and advocacy. The technical and management standards developed with our more than 10,000 members improve safety, health, the environment, and economic efficiency in Canada and beyond.

CSA Group always strives to provide up to date and accurate information. However, no representation or warranty, expressed or implied, is made that this information meets your specific needs and any reliance on this information is at your own risk. Please contact CSA Group for more information about our services.

