

Concrete Framed Construction: Design, Performance and Environmental Impact

Introduction

Concrete has become one of the most dominant materials in modern construction, particularly in the development of large-scale commercial and high-rise buildings. Its widespread use is driven by its strength, durability, and ability to be formed into a wide range of structural configurations. However, these advantages are increasingly being challenged by concerns surrounding environmental impact and long-term sustainability. This essay examines a major UK-based concrete framed building, analysing its design and construction methods, before critically evaluating the performance of concrete as a framing material. It then explores the wider environmental and community impacts associated with concrete production.

1. Case Study: One Canada Square, London

A significant example of concrete framed construction in the UK is One Canada Square, located in Canary Wharf, London. Completed in 1991 and designed by César Pelli, the building stands at 235 metres and was the tallest structure in the UK for over two decades. It continues to serve as a major commercial office building within London's financial district.

Original Design Elements

The design of One Canada Square must be understood within the context of the wider regeneration of London's Docklands. This redevelopment aimed to transform a declining industrial area into a globally competitive financial centre. According to the Canary Wharf Group (2020), the building was intended to act as a landmark, symbolising economic renewal and modernity.

Architecturally, the building adopts a simple and efficient form, with a square footprint and strong vertical emphasis. This reflects the need to maximise usable office space while maintaining structural efficiency. The distinctive pyramidal roof provides a recognisable identity, drawing on classical architectural influences (Pelli Clarke Pelli Architects, 2012).

A key feature of the building's design is its reinforced concrete core. This core acts as the primary structural element, housing lifts, staircases, and service risers while also resisting lateral forces such as wind. In high-rise construction, lateral stability is a critical factor, and concrete cores are widely used due to their stiffness and mass (Chudley and Greeno, 2016). The decision to utilise a concrete core reflects a strategic balance between structural performance and functional requirements.

Surrounding the core is a steel frame, which supports the floor plates and enables large, open-plan office spaces. This hybrid structural system allows for flexibility in internal layout, an important consideration for commercial tenants. The Institution of Structural Engineers (2020) highlights that combining concrete cores with steel framing is a common approach in high-rise construction, as it maximises both structural efficiency and adaptability.

The design also reflects an awareness of long-term usability. The open floor plates allow tenants to modify internal layouts with relative ease, ensuring the building can accommodate changing commercial needs over time. This demonstrates an early recognition of lifecycle thinking in building design.

Method of Construction

The construction of One Canada Square demonstrates the practical application of concrete framing techniques in a large-scale project. The central core was constructed using slip-forming, a method that allows continuous pouring of concrete within a moving formwork system. This technique enabled rapid vertical construction and improved structural consistency (Neville, 2011).

Slip-forming was particularly effective in this case, as it reduced construction time while maintaining high quality. Bennett (2003) notes that such methods were instrumental in enabling efficient high-rise construction during the late twentieth century.

High-strength concrete was used throughout the core to withstand significant vertical and lateral loads. Advances in material technology allowed for improved performance characteristics, including increased compressive strength and durability (Mehta and Monteiro, 2014). This was essential for ensuring the building's long-term structural integrity.

The steel frame and floor systems were constructed concurrently with the concrete core, illustrating a coordinated construction programme. Prefabricated steel elements were manufactured off-site and assembled on-site, reducing labour requirements and improving efficiency. This hybrid approach reflects broader industry trends towards integrating different materials to optimise performance (Pacheco-Torgal et al., 2013).

The foundation design was also critical due to the Docklands site conditions. Deep piled foundations were used to transfer loads to stable strata, ensuring the building's stability. This highlights the importance of geotechnical considerations in determining construction methods.

Overall, the construction of One Canada Square illustrates how concrete framing can be effectively integrated with other materials to deliver a high-performance and adaptable structure.

2. Analysis of Concrete Framing Material

Strength, Durability and Climatic Resistance

Concrete is widely recognised for its high compressive strength, making it ideal for load-bearing structures. When reinforced with steel, it is capable of resisting both compressive and tensile forces. Neville (2011) notes that high-strength concrete can exceed 100 MPa, making it particularly suitable for high-rise construction.

Durability is another key advantage. In urban environments such as London, buildings are exposed to moisture, pollutants, and temperature variation. Concrete performs well under these conditions, provided it is properly designed and maintained. Mehta and Monteiro (2014) emphasise that its resistance to environmental degradation contributes to long service life.

The climatic conditions in London are relatively moderate, but wind loads at height remain a significant factor. The concrete core provides the necessary stiffness to resist these forces. Additionally, concrete offers excellent fire resistance, which is essential in high-rise buildings.

However, concrete is not without limitations. Carbonation and chloride ingress can lead to reinforcement corrosion if not properly managed. This highlights the importance of maintenance and quality control throughout the building's lifecycle.

Time, Labour, Programme and Cost Compared to Steel Framing

Concrete construction generally involves longer programme durations due to curing requirements. However, methods such as slip-forming can significantly improve efficiency. Labour requirements are typically higher, as multiple stages are involved in the construction process.

Steel framing offers advantages in speed and reduced labour due to off-site fabrication. However, concrete is often more cost-effective in terms of raw materials. The overall cost depends on project-specific factors, including scale and complexity (Institution of Structural Engineers, 2020).

Ease of Assembly and Adaptability

Concrete frames are less flexible during construction but provide strong and stable structures once completed. The central core design allows for open floor plates, which can be adapted to different uses.

However, structural modifications are more difficult compared to steel, limiting adaptability in some cases.

Integration of Services Provision

The integration of services within concrete structures requires careful planning. Services must be incorporated during the design phase, as retrofitting is challenging. In One Canada

Square, services are housed within the core and distributed through floor and ceiling systems.

Chudley and Greeno (2016) emphasise the importance of coordination between disciplines to ensure efficient integration.

Demolition and End-of-Life Challenges

Concrete demolition is complex and resource-intensive. Reinforced concrete is difficult to process, and materials are often downcycled rather than fully recycled. Pacheco-Torgal et al. (2013) highlight the environmental impact of demolition, including waste generation and energy use.

In dense urban environments, these challenges are further increased, making deconstruction a more sustainable alternative.

While concrete framing offers clear structural and durability advantages, a more critical comparison with steel framing reveals a nuanced balance between performance, efficiency, and long-term value. In high-rise construction such as One Canada Square, the choice of a reinforced concrete core alongside a steel frame reflects a deliberate hybrid strategy rather than a reliance on a single material system.

Steel framing is often favoured for its speed of construction, as components can be fabricated off-site and rapidly assembled on-site. This can significantly reduce programme duration, which is a major advantage in commercial developments where time equates to financial return. In contrast, concrete requires curing time, which can slow progress despite the use of advanced techniques such as slip-forming. However, this apparent disadvantage can be partially offset by the inherent fire resistance of concrete, which reduces the need for additional fire protection measures that are typically required in steel structures (Chudley and Greeno, 2016).

From a structural perspective, concrete cores provide superior stiffness compared to steel alternatives, particularly in resisting lateral loads such as wind. This is especially important in tall buildings, where excessive movement can affect both structural performance and occupant comfort. The use of concrete in the core of One Canada Square demonstrates how this material can enhance overall building stability while allowing steel to be used more efficiently in areas where flexibility is required.

Cost considerations also highlight important trade-offs. While steel may offer savings in time and labour, it is generally more expensive as a raw material. Concrete, by contrast, is relatively inexpensive and widely available, making it an attractive option for large-scale projects. However, the total cost must account for labour, construction time, and long-term maintenance. According to the Institution of Structural Engineers (2020), the most cost-effective solution is often achieved through a hybrid approach that leverages the strengths of both materials.

Another important factor is lifecycle performance. Concrete structures tend to require less maintenance over time due to their durability and resistance to environmental factors. Steel

structures, while strong and lightweight, are more susceptible to corrosion and may require ongoing protective treatments. This difference can influence long-term operational costs and sustainability considerations.

Ultimately, the comparison between concrete and steel framing highlights that neither material is inherently superior in all contexts. Instead, their effectiveness depends on how they are applied within the overall design. In the case of One Canada Square, the combination of a concrete core with a steel frame represents a carefully considered solution that balances structural performance, construction efficiency, and adaptability.

3. Environmental and Community Impact of Concrete Production

Concrete production has significant environmental implications, particularly due to cement manufacturing. Andrew (2018) estimates that cement production accounts for approximately 7–8% of global carbon emissions.

The process involves heating limestone at high temperatures, releasing carbon dioxide through both combustion and chemical reactions. The International Energy Agency (2022) emphasises the need for improved efficiency and alternative fuels to reduce emissions.

The extraction of raw materials can lead to habitat destruction and landscape degradation. Additionally, production consumes large amounts of energy and water.

Concrete production also impacts local communities. Quarrying and manufacturing can generate noise, dust, and increased traffic, affecting quality of life. Construction activities can cause further disruption, particularly in urban areas.

Despite these challenges, concrete remains essential for infrastructure development. Efforts to reduce its impact include the use of supplementary materials and sustainable practices promoted by the World Green Building Council.

Beyond its immediate environmental impacts, the continued reliance on concrete raises broader questions about the future of construction in the context of global sustainability goals. The scale of cement production required to support urban development is immense, and despite incremental improvements in efficiency, emissions remain high. This creates a tension between the demand for infrastructure and the need to reduce carbon output.

One emerging area of focus is the concept of embodied carbon, which refers to the total emissions associated with the production, transport, and installation of construction materials. Concrete contributes significantly to embodied carbon in buildings, particularly in high-rise structures where large volumes are required. Organisations such as the World Green Building Council have emphasised the need to address embodied carbon alongside operational emissions in order to achieve meaningful reductions in the built environment.

Innovations in material science offer some potential solutions. The development of low-carbon cements, as well as the increased use of recycled materials, could help reduce

the environmental impact of concrete production. Additionally, carbon capture technologies are being explored as a means of offsetting emissions generated during cement manufacturing. However, these solutions are still in the early stages of widespread adoption and face economic and technical challenges.

There is also a growing emphasis on designing buildings for longevity and adaptability, which can reduce the need for demolition and reconstruction. In this context, the durability of concrete can be seen as both an advantage and a challenge. While long-lasting structures reduce the frequency of replacement, their eventual demolition can have significant environmental consequences.

A more sustainable approach may involve rethinking how concrete is used, rather than eliminating it entirely. This includes optimising structural design to minimise material use, incorporating alternative materials where appropriate, and improving recycling processes at the end of a building's life. The future of concrete construction will therefore depend not only on technological innovation but also on changes in design philosophy and industry practice.

Conclusion

One Canada Square demonstrates the effectiveness of concrete framing in high-rise construction. Its reinforced concrete core provides strength, durability, and stability, while supporting flexible internal spaces.

However, concrete also presents challenges, including construction time, service integration, and environmental impact. While it remains a vital material, its future depends on the industry's ability to adopt more sustainable practices.

4. The following particle size distribution was obtained from a sieve analysis on an 'all-in' aggregate used for concrete production. The original sample size was 1250g

Sieve size (mm)	Mass (g)	% on sieve	% Passing
125	0	0	100
75	0	0	100
63	0	0	100
37.5	120	9.6	90.4
20	137	10.96	79.44
10	143	11.44	68

6.3	105	8.4	59.6
3.35	45	3.6	56
2	130	10.4	45.6
1.18	63	5.04	40.56
0.6	105	8.4	32.16
0.3	102	8.16	24
0.212	109	8.72	15.28
0.15	98	7.84	7.44
0.063	55	4.4	3.04

B. Calculate percentage of fine and coarse aggregate in the mix

- Fine aggregate - 56%
- Coarse aggregate- 44%

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