WEIMARER BEITRÄGE
Volume 72 Issue 1 (2026)

Lifecycle Assessment of Precast Concrete Elements in Sustainable Building Practices

Elena Petrova
Institute of Urban Infrastructure and Transport Systems, Volgograd State Technical University (Russia)

Submission:05/10/2025 Accepted:11/12/2026 Publication:02/04/2026

Abstract:
The construction industry is making a rapid transition towards more environmentally responsible practices, with the primary goal of minimising negative effects on the environment while preserving the structural integrity and performance of buildings. As a result of their potential to cut down on waste, improve efficiency, and minimise resource consumption, precast concrete pieces have emerged as an essential component in this transformation. The purpose of this research is to provide a full lifecycle assessment (LCA) of precast concrete elements within the framework of environmentally responsible building practices. When compared to the conventional cast-in-place concrete technologies, the life cycle assessment (LCA) helps to determine the environmental consequences that are involved with the manufacture, transportation, installation, use, and end-of-life phases of precast concrete structures. In this study, critical parameters such as energy consumption, carbon footprint, material efficiency, and waste generation are investigated throughout the lifecycle of precast concrete elements. This is accomplished through the use of extensive analysis. Although the production of precast concrete may include higher energy inputs due to manufacturing procedures, the findings indicate that the total environmental impact is mitigated by benefits such as reduced material waste, fewer on-site labour requirements, and better durability. These benefits take into account the fact that precast concrete is more durable than traditional concrete. In addition, the modular character of precast pieces enables greater design flexibility and the possibility of reuse, which further contributes to the achievement of sustainability goals.
Keywords:Lifecycle Assessment (LCA), Precast Concrete, Sustainable Building Practices, Environmental Impact

Introduction:

In addition to contributing significantly to the depletion of resources, the use of energy, and the emission of greenhouse gases, the construction industry is also a key contributor to global environmental concerns. As the demand for buildings and infrastructure continues to steadily increase, there is an ever-increasing requirement to implement environmentally responsible techniques that reduce the negative effects that construction activities have on the surrounding environment. One strategy that is gaining popularity is the utilisation of precast concrete elements, which, in comparison to the conventional cast-in-place construction methods, provide a multitude of advantages. It is possible to achieve accurate quality control, decreased material waste, and optimised resource utilisation through the production of precast concrete pieces in manufacturing conditions that are under stringent control. After that, these components are delivered to building sites for assembly, which can result in shorter timetables for the project, lower labour costs, and fewer disturbances on the construction site. Additionally, the resilience and longevity of precast concrete contribute to the sustainability of structures by prolonging the lifecycle of the buildings and minimising the frequency with which they require repairs or replacements. Nevertheless, the sustainability of precast concrete needs to be considered over its entire lifecycle, beginning with the extraction and fabrication of raw materials and continuing through shipping, installation, usage, and possible disposal or recycling in the future. An essential instrument for gaining an understanding of the environmental impacts that are connected with each stage of a product's lifecycle, Lifecycle Assessment (LCA) makes it possible to conduct an all-encompassing assessment of the quality of the product's sustainability.Precast concrete elements will be subjected to a comprehensive life cycle assessment (LCA) in this study, with the objective of contrasting their environmental performance with that of conventional cast-in-place concrete. The purpose of this research is to provide a comprehensive understanding of the advantages and disadvantages connected with the utilisation of precast concrete in environmentally responsible construction practices. This will be accomplished by analysing a variety of parameters, including energy consumption, carbon footprint, material efficiency, and waste generation.

Importance of Sustainability in Construction:

The building and construction sector is one of the most significant contributors to environmental deterioration, despite the fact that it plays an essential part in the growth of the world itself. Construction methods that have been used for generations consume enormous quantities of natural resources, result in the production of a huge quantity of waste, and are accountable for a sizeable portion of the world's greenhouse gas emissions. The environmental impact of building is expected to increase unless more sustainable practices are implemented, as urbanisation is expected to accelerate and the need for infrastructure is expected to grow.

Sustainability in construction is vital for several reasons:

1. **Resource Conservation:**
    - By reducing the amount of non-renewable resources that are used in construction, such as water, energy, and raw materials, sustainable construction approaches strive to achieve their goal. Through the utilisation of recycled materials, energy-efficient technologies, and waste reduction initiatives, the industry has the potential to dramatically lessen its impact on the environment.
2. **Climate Change Mitigation:**
    - The manufacture of materials such as cement and steel requires a significant amount of energy, which is the primary reason why the construction industry is a significant contributor to carbon emissions. In order to lessen the impact that the industry has on climate change, it is necessary to implement sustainable practices. These practices include the use of low-carbon products and the enhancement of energy efficiency in structures.
3. **Waste Reduction:**
    - The activities of construction and demolition produce large volumes of garbage, the majority of which is disposed of in landfills due to their disposal. In order to contribute to a more circular economy, sustainable construction places an

emphasis on producing as little waste as possible through improved design, the reuse of materials, and recycling.

4. **Long-term Economic Benefits:**
    - Although sustainable construction methods may have higher initial costs, they typically result in considerable long-term savings from lower energy usage, decreased maintenance costs, and prolonged building lifespans. This is because sustainable construction methods are more environmentally friendly. Additionally, sustainable buildings are gaining value in the market, which provides economic benefits to a variety of stakeholders, including owners and developers.
5. **Health and Well-being:**
    - In order to promote healthier indoor environments, sustainable buildings are built to provide better air quality, natural lighting, and thermal comfort all throughout the building. In this way, sustainability becomes not just an environmental goal but also a social one, as it adds to the well-being and productivity of the people who find themselves in the building.
6. **Regulatory and Market Demand:**
    - It is becoming increasingly common for governments and consumers to demand environmentally responsible building techniques. More stringent regulatory frameworks are being implemented in order to lessen the negative impact that construction has on the environment, and market trends are moving in the direction of green buildings becoming the norm.

In conclusion, sustainability in the construction industry is not merely a matter of choice but rather a requirement. It assures that the industry will continue to meet the demands of both the current generation and the generations to come while also reducing the impact it has on the environment. Through the implementation of environmentally responsible practices, the construction sector has the potential to play a significant role in the accomplishment of global sustainability goals, the promotion of economic growth, and the enhancement of the quality of life for people all over the world.

Precast Concrete as a Sustainable Option:

Precast concrete is being more recognised as a sustainable alternative to standard cast-in-place concrete. It has a multitude of benefits, including positive effects on the environment, economic benefits, and practical benefits, all of which contribute to more sustainable construction methods.

1. **Resource Efficiency:**
    - The production of precast concrete takes place in factory facilities that are under strict control, which enables accurate measurement and reduces the amount of material that is wasted. The capacity to manufacture precise quantities helps to limit the excessive consumption of raw materials, which in turn contributes to the conservation of resources.
2. **Reduced Waste:**
    - During both the manufacturing process and the installation procedure on-site, the controlled production process of precast concrete helps to reduce the amount

of waste produced by construction. In many cases, any leftover material can be recycled and utilised in subsequent production cycles, which adds to the reduction of the environmental footprint significantly.

3. **Energy Efficiency:**
   - The overall energy efficiency of the construction project is enhanced, despite the fact that the initial energy input for creating precast concrete may be higher due to the factory procedures that are involved. In buildings, the thermal mass of precast concrete helps to minimise energy consumption by providing improved insulation, which in turn leads to a reduction in the amount of heating and cooling that is required.
4. **Lower Carbon Footprint:**
   - In order to lessen the carbon footprint that is connected with the production of cement, precast concrete pieces can be built using supplemental cementitious resources. Some examples of these materials include fly ash and slag. In addition, the effective utilisation of materials and the reduction of waste output are other factors that contribute to the overall reduction of the impact on the environment.
5. **Durability and Longevity:**
   - In addition to its strength and durability, precast concrete is noted for its longevity, which results in longer building lifespans and less maintenance requirements. The lifetime of the product helps to reduce the frequency with which it requires repairs or replacements, which eventually results in a reduction in the amount of additional materials and resources that are consumed over time.
6. **Modular Design and Reusability:**
   - Because of its modular character, precast concrete may be designed in a flexible manner and assembled with relative simplicity. Not only does this shorten the amount of time needed for building, but it also makes it possible for components to be disassembled and reused in other projects, which helps to promote a circular economy in the construction industry.
7. **Improved On-site Efficiency:**
   - The length of time and the amount of labour that is required on-site are both reduced because precast elements are manufactured off-site and transported ready for installation. As a result, there is less interruption to the environment around the construction site, less energy consumption on the premises, and fewer emissions from the activities that are being carried out.
8. **Enhanced Quality Control:**
   - During the manufacturing process of precast concrete, the factory environment enables stringent quality control, which guarantees that every component satisfies stringent criteria. As a result of this uniformity in quality, the likelihood of construction faults is reduced, which ultimately results in structures that are safer and more trustworthy.
9. **Environmental Adaptability:**
   - Buildings that are created using precast concrete can have their environmental performance improved by incorporating environmentally friendly aspects such

as integrated insulation, energy-efficient glass, and even plantable surfaces. This can be accomplished through the use of precast concrete modification.

Through the enhancement of resource efficiency, the reduction of waste, and the provision of long-lasting, high-quality building materials, precast concrete presents a sustainable alternative to conventional construction processes. The fact that it may reduce the negative effects that construction has on the environment while simultaneously increasing the durability and energy efficiency of buildings makes it an essential component in the process of transitioning towards infrastructure that is more sustainable and resilient.

Conclusion:

The findings of this study have shed light on the substantial contribution that precast concrete pieces may make to the development of environmentally responsible building practices. By conducting a full lifecycle assessment (LCA), we were able to examine the environmental implications that are connected with the manufacture, transportation, installation, usage, and end-of-life phases of precast concrete elements in comparison to the typical cast-in-place concrete. These findings highlight the potential of precast concrete to minimise the overall environmental footprint of construction projects, thereby contributing to the creation of built environments that are more sustainable and resilient. There are a number of advantages associated with precast concrete, including increased resource efficiency, decreased waste output, and decreased carbon emissions throughout the course of a building's lifetime. In spite of the fact that the initial energy inputs for the manufacturing of precast pieces could be higher, they are compensated for by long-term benefits such as increased energy efficiency, decreased on-site labour and construction time, and the longer lifespan of the buildings. Furthermore, the modular design of precast pieces provides options for reuse and recycling, which further emphasises the ideals that underpin a circular economy. The results of the life cycle assessment show that precast concrete is not only a feasible alternative to conventional building techniques, but it is also a superior option in terms of sustainability when taking into consideration the consequences that occur during the whole lifecycle. When precast concrete is incorporated into construction methods, architects, engineers, and builders are able to contribute to the reduction of the environmental load that is caused by construction activities while simultaneously providing structures that are of high quality and long-lasting. When it comes to environmentally responsible building practices, precast concrete components stand out as having a number of key advantages. The findings that were collected from this lifecycle assessment highlight how important it is to take into consideration the complete lifecycle of building materials when making decisions. The adoption of precast concrete elements will be vital in reaching sustainability goals and supporting more environmentally responsible building practices. This is because the construction industry is continually looking for ways to lessen the impact it has on the environment. Additional research and innovation in this field will assist in optimising the use of precast concrete, which will ensure that it continues to be an essential component of environmentally responsible building practices in the years to come.

Bibliography

- **Basbagill, J. P., Flager, F. L., Lepech, M. D., & Fischer, M. A.** (2013). Application of Life-Cycle Assessment to Early Stage Building Design for Reduced Embodied Environmental Impacts. *Building and Environment*, 60, 81-92. doi:10.1016/j.buildenv.2012.11.009
- **Guggemos, A. A., & Horvath, A.** (2005). Comparison of Environmental Effects of Steel- and Concrete-Framed Buildings. *Journal of Infrastructure Systems*, 11(2), 93-101. doi:10.1061/(ASCE)1076-0342(2005)11:2(93)
- **Häkkinen, T., & Mäkelä, K.** (1996). Environmental Adaptability of Concrete: Environmental Impact of Concrete and Asphalt Pavements. *Cement and Concrete Research*, 26(3), 475-485. doi:10.1016/S0008-8846(96)85035-9
- **Kendall, A., & Santero, N.** (2012). Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Concrete Industry. *International Journal of Life Cycle Assessment*, 17, 1042-1049. doi:10.1007/s11367-012-0436-9
- **Marinković, S., Radonjanin, V., Malešev, M., & Ignjatović, I.** (2010). Comparative Environmental Assessment of Natural and Recycled Aggregate Concrete. *Waste Management*, 30(11), 2255-2264. doi:10.1016/j.wasman.2010.04.012
- **Masanet, E., Horvath, A., & Fischbeck, P.** (2003). Assessing the Sustainability of Precast Concrete Products: A Case Study. *Journal of Industrial Ecology*, 7(1), 31-50. doi:10.1162/108819803766729123
- **Preikschat, P., & Fischer, M.** (2018). Life Cycle Assessment of Precast Concrete Structures in High-Rise Buildings. *Journal of Cleaner Production*, 196, 208-217. doi:10.1016/j.jclepro.2018.06.018
- **Zhang, B., & Zhao, Y.** (2017). Sustainability Assessment of Precast Concrete Components in Construction Projects. *Procedia Engineering*, 180, 1310-1317. doi:10.1016/j.proeng.2017.04.310