Scaling up the sustainability and circular economy transition: Precast Concrete Advantages

Introduction

The construction sector, one of the largest contributors to global carbon emissions, has a big responsibility on adopting sustainable and circular practices. As sustainability and circular economy policies tighten and trends shift towards novel solutions, the collaboration between policymakers, industry and society becomes crucial. In line with this paradigm shift, sustainable construction encompasses three key pillars: environmental, economic, and social.

Concrete as material has several advantages from the sustainability and circularity point of view. It provides construction works with strength, resilience, durability, long service life, reduced emissions and energy efficiency. It is affordable and available at the local level, minimising transport emissions and costs. The full concrete structure can be reused, bringing up circularity. Concrete acts as a long-term carbon sink through carbonation, and this process is enhanced when concrete is crushed at the end of its life cycle. Additionally, concrete's thermal mass helps regulate building temperatures, reducing heating and cooling energy demands, and its recyclability further contributes to waste reduction and resource conservation.

When the benefits of concrete are coupled with **factory-made production processes**, the result is "**Precast Concrete**", a sustainable building solution, aligning with the three key pillars to offer significant advantages [1]. This paper demonstrates the additional benefits of precast concrete for the sake of sustainability and circular economy and argues for its broader adoption to meet the growing need for sustainable construction. By highlighting its environmental benefits, economic efficiencies, and social contributions, this paper aims to demonstrate how precast concrete can drive the construction ecosystem and finally the society towards a more sustainable future.

Environmental Pillar

1. Low embodied and operational carbon

While considering the whole carbon approach, precast concrete has the potential to significantly **reduce both embodied and operational carbon emissions** [2]. The precast concrete structure can be optimised through engineering to reduce the whole life carbon emissions for a given functional unit [3]. Its manufacturing in a controlled environment ensures that was is designed is built, with no surprises. It is usually characterised by leaner structures with concrete and reinforcement only where necessary.

2. Use of low-carbon binders

By integrating low-carbon cement alternatives, the environmental footprint of precast concrete can be minimised [4]. These materials not only reduce carbon emissions but also promote the recycling of industrial by-products, contributing to a circular economy.

The use of low-carbon binders can pose some difficulties (namely the usually lower early strength), but taking profit of the factory environment one can:

- Add supplementary cementitious materials, additions and fillers to find the best mix
- Use the right admixtures
- Work on curing environment and time

It is a matter of **optimisation on the final product**!

3. Use of alternative raw materials

The factory environment facilitates the incorporation of **alternative materials** like fly ash, slag, and recycled aggregates into precast concrete mixes, thus reducing the demand for virgin materials and leveraging industrial by-products. This approach helps conserve resources and decrease the overall environmental impact of manufacturing. Concerning **reinforcement**, it is both possible to use recycled steel and alternative reinforcements (fibres, meshes etc…) made of other non-ferrous materials [5]. This can further enhance sustainability by reducing the need for new steel production and sometimes reduce the total amount of concrete needed linked with a reduced cover.

4. Energy efficiency

Precast concrete manufacturing can implement energy-efficient practices, such as through heat-storage capacity and utilising recycled heat from curing processes and adopting **renewable energy** systems like solar or wind power locally produced in the factory. Renewable energy for example can be produced at the factory where the precast element is casted, thus avoiding the need for storing or transporting it to the construction site. These practices not only reduce the overall energy consumption associated with concrete manufacturing but also lower greenhouse gas emissions.

At the level of buildings, precast solutions can be designed for the **optimum thermal properties** by incorporating different types of insulations and other systems (e.g. piping in floors) that allows to take the full profit of the concrete thermal performances [6].

5. Waste reduction

Precast concrete generates **less construction waste** compared to traditional methods due to its precise manufacturing process [7]. Efficient use of materials, reduction of excess, and recycling of wastewater in the production cycle contribute to a lower environmental impact and reduced landfill waste at the manufacturing stage. Additionally, **wastes on the construction site are also reduced**, because the precast product usually arrives semi-finished, thus requiring a lower quantity of finishing materials.

6. Transportation

With approximately 8.000 precast concrete plants spread throughout the European continent, precast concrete components are **manufactured close to construction sites**. This localised production reduces transportation distances, leading to lower fuel consumption and emissions, and mitigates traffic congestion and wear on transportation infrastructure.

7. Water management

Preservation of water is a key challenge for the coming years. Precasting concrete allows for several **reductions in water consumption** and its more efficient management.

- Less water is used in concrete (normally between 0,36 and 0,38 water to binder ratio, less than in a typical mix) [8]
- There is the possibility to recycle used and unused water (closed loop manufacturing)
- No water is needed on the construction site, where its management is more difficult
- Rainwater can be collected and directly used at the precast plant [9]

During the use phase, Precast concrete solutions for paving and water pipes facilitate **effective groundwater management**, reducing the risk of flooding and improving water quality. It can also aid in rainwater infiltration with permeable solutions, enhancing the sustainability of urban water management systems.

8. Biodiversity

Precast concrete can be integrated with **green facades and roofs**, supporting urban biodiversity. These green spaces provide habitats for various species, enhancing urban ecosystems and contributing to human physical and mental health. The inclusion of greenery in urban areas has been shown to reduce stress, **improve air quality**, and foster a sense of well-being among residents. On the other hand, in off-site terms, gravel pits can contribute to biodiversity while creating nutrient-poor areas that attract rare species and preserving natural features like rocks and water surfaces [10].

Economic Pillar

1. Circularity principles

Precast concrete manufacturing supports circularity principles through its **durability**, **ease of maintenance**, **repairability**, possibility of **reuse** and **recyclability**. Modular construction with precast components allows buildings to stay in use longer, be adapted more easily, and contribute to a sustainable lifecycle. This **adaptability extends the lifespan of structures**, let it stay in the loop, therefore reducing the need for new construction and conserving resources [11].

Additionally, precast concrete elements can be deconstructed at the end of the service life of the construction work and reused (with or without repurposing operations) [12].

2. Local availability

Local manufacturing of precast concrete components minimizes transportation costs and **supports regional economies**. This proximity also ensures faster delivery times and reduces construction delays, promoting more efficient project timelines and lower costs.

3. Quality control

Precast concrete is produced in controlled factory environments, resulting in high-quality products with minimal defects. This precision reduces the likelihood of construction errors and associated delays, enhancing overall **project efficiency and reducing costs** associated with rework and repairs [14].

4. Speed of construction

Due to the advanced completion status when a precast solution comes to the construction site, the erection speed can be reduced compared to traditional solutions. Saving time means saving money, with the final construction work available early for its economic operation [15].

5. Material efficiency

Precast concrete elements require **smaller quantities of concrete and reinforcement** compared to onsite concrete constructions due to their high material efficiency. This is ensured by standardised and optimised design and very high production accuracy of the precast concrete elements.

6. Digitally ready

Precast concrete has profound competence in digital planning and reporting solutions such as Building Information Management (BIM). Therefore, this allows the **holistic and efficient planning**, constructing and managing buildings.

Social Pillar

1. Providing value to society

Precast concrete contributes to **healthier and more valuable indoor environments** by accumulating a range of sustainability advantages. These benefits combine to create spaces that are not only more eco-friendly but also enhance the well-being of the occupants.

Finishing of internal and external buildings **can be achieved at the factory level** (with or without covering the concrete surface). The aesthetics of the building is also improved with less material and operations. [15]

2. Healthy indoor environments

Precast concrete contributes to healthier indoor environments as it is **emission-free and does not release volatile organic compounds** (VOCs) or other harmful substances. This creates a healthier living and working environment, reducing the risk of respiratory issues and other health problems. The **controlled factory environment** ensures that Precast concrete does not leach harmful chemicals into the environment, ensuring that both indoor and outdoor spaces remain free from contamination. This contributes to overall environmental health and safety [15].

3. Prevention of mildew and mould

Due to a usually high compaction that ensures its **non-porous nature**, precast concrete resists moisture, preventing the growth of mildew and mould. Additionally, it is impervious to insect attacks, ensuring a longer lasting and healthier building environment.

4. Resilient

The robust nature of precast concrete also means buildings are more resilient to environmental hazards, providing **safer and more secure homes and workplaces**. Construction mistakes are minimised, which also contributes to a better resilience and robustness [16].

5. Healthy and safe in operations

Workers' safety is enhanced in precast factories by **reducing exposure to hazardous conditions**. Additionally, the minimized on-site construction activities lower the risk of accidents and improve overall site safety.

6. Fire resistant

Precast concrete elements are extremely fire-resistant due to their **non-flammability** and high thermal inertia. Should a fire nevertheless occur in the building, the concrete components do not give off any harmful fumes or gases, nor they add combustible material to the fire [17].

7. Reducing nuisance on the construction site

With precast, the construction work has only to be **assembled** on the construction site. Therefore, less space is necessary and, with on time delivering, it can also be done fast: nuisance is finally minimised [18].

8. Soundproof

Due to its high density, precast concrete elements have **excellent sound and vibration-damping properties**. They provide effective protection against noise and are the right choice especially near paved roads, railway lines or in-flight paths.

9. Architectural diversity

Precast concrete can be manufactured in different **dimensions**, **colours**, **shapes** and **surface textures**. There are no limits to the possibilities. The surfaces of precast concrete are of high quality and, in the case of tiling and wallpapering, save the need for installation.

Conclusion

Precast concrete stands out as a sustainable construction material that aligns with the **environmental, economic, and social pillars of sustainability and circular economy transition**. Its advantages in reducing carbon emissions, promoting circular economy principles, ensuring high-quality construction, improving health and safety and contribution to the social pillar make it a compelling choice for modern construction projects. As policies and industry trends continue to emphasise sustainability, the adoption of precast concrete can play a pivotal role in achieving a more sustainable and resilient built environment.

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Secretariat :
Rue d'Arlon 55
B-1040 Brussels

Contact :
info@bibm.eu
https://bibm.eu