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Key Considerations for Swedish Construction Firms in Selecting Sustainable Concrete

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Abstract

Traditional Portland cement-based concrete remains a dominant material in construction, yet its environmental impact is significant, contributing 5-8% of global carbon dioxide emissions. This has spurred an increasing demand for more sustainable concrete alternatives. However, Swedish construction firms appear hesitant to transition to newer, eco-friendly materials and construction techniques. This study seeks to identify the critical factors influencing Swedish companies' decisions to adopt environmentally friendly concrete (EFC). The research methodology includes a comprehensive literature review and a structured survey. The survey evaluates the importance of various criteria associated with EFC, with respondents rating these factors. The findings highlight that long-term performance is the most valued characteristic, whereas the imposition of greenhouse gas emission caps on companies is the least prioritized factor.

Keywords: *Environment, Concrete, Adoption, Construction, Industry.*

1. Introduction

Portland cement-based concrete (PCBC) is a fundamental material in modern construction, valued for its strength, durability, and versatility in residential, commercial, and infrastructure projects. Its role in forming load-bearing structures ensures the stability and safety of buildings, bridges, and other critical infrastructure (Smith et al., 2019). However, the environmental impact of PCBC is considerable, as the cement industry accounts for 5-8% of global anthropogenic CO_2 emissions, largely due to the calcination of limestone, which releases significant amounts of carbon dioxide during cement production (IEA, 2021; Lehne & Preston, 2018). This substantial environmental cost has prompted global efforts to identify more sustainable alternatives, with countries like Sweden leading the charge toward climate neutrality.

Sweden has set ambitious climate goals, aiming for net-zero greenhouse gas emissions by 2045, five years ahead of the European Union's target of achieving climate neutrality by 2050 (Swedish Government, 2017). To meet this objective, Sweden must reduce emissions by 85% compared to 1990 levels, with the remaining emissions offset by carbon capture and other mitigation technologies (Andersson et al., 2020). The construction sector, responsible for 10-30% of Sweden's carbon emissions, plays a crucial role in achieving these targets (Boverket, 2020). This sector's environmental impact arises not only from cement production but also from energy consumption during building operations and waste generation (Gustavsson et al., 2019). Furthermore, urbanization and population growth in Sweden

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have intensified the demand for new housing and infrastructure, exacerbating the challenge of reducing the sector's carbon footprint (Johansson & Nilsson, 2021).

One promising solution to this challenge is the adoption of environmentally friendly concrete (EFC), which incorporates alternative materials such as industrial by-products, recycled aggregates, and supplementary cementitious materials (SCMs) to reduce its carbon intensity (Scrivener et al., 2018). EFC reduces reliance on Portland cement, the primary source of emissions in concrete production, by substituting cement with materials like fly ash, slag, silica fume, and calcined clays (Taylor, 2020). These materials, often by-products of industrial processes, reduce waste and lower the carbon footprint of concrete (Mehta, 2001). For instance, fly ash, a by-product of coal combustion, can replace up to 30% of cement in concrete without compromising its strength or durability (Malhotra, 2002). Additionally, the use of recycled aggregates from construction and demolition waste helps conserve natural resources and reduces the energy needed for mining virgin materials (Oikonomou, 2005).

Despite its potential, the widespread adoption of EFC in Sweden faces several challenges. Construction firms have traditionally been cautious about adopting new materials due to concerns over performance, regulatory compliance, and cost-effectiveness (Lindblad & Eriksson, 2020). The Swedish construction industry is highly regulated, and any new material, including EFC, must undergo rigorous testing and certification to ensure it meets safety and performance standards (Boverket, 2021). This process can be time-consuming and costly, dissuading firms from experimenting with new materials (Hansen et al., 2019). Additionally, the unfamiliarity with EFC among contractors, engineers, and architects, combined with variations in EFC formulations based on local material availability, further complicates its widespread adoption (Miller et al., 2018; Taylor, 2020).

Cost is another significant barrier. While EFC can reduce carbon emissions, its production is often more expensive than traditional concrete, particularly in the short term (Gursel et al., 2016). The expenses associated with sourcing and processing alternative materials, along with additional testing and certification, can increase construction costs (Knoeri et al., 2013). For many firms, these financial risks outweigh the environmental benefits (Lindblad & Eriksson, 2020).

Overcoming these challenges requires substantial legislative changes and technological advancements. Policymakers must develop a regulatory framework that encourages the use of EFC while ensuring compliance with industry standards. This could include incentives such as tax breaks or subsidies for firms that adopt sustainable practices (Johansson & Nilsson, 2021). Furthermore, building codes and standards should be updated to recognize EFC as a viable alternative to traditional concrete (Taylor, 2020). Technological innovation is also essential, with research focused on improving the mechanical properties, durability, and scalability of EFC to facilitate its broader use (Scrivener et al., 2018). Advancements such as nanotechnology and self-healing concrete offer promising solutions for enhancing the longevity and performance of EFC (Sanchez & Sobolev, 2010; Jonkers et al., 2010).

Collaboration among industry stakeholders, researchers, and policymakers is crucial to driving EFC adoption in Sweden. Industry associations, research institutions, and government agencies must work together to establish best practices and promote successful case studies, demonstrating the feasibility of EFC in real-world applications (Boverket, 2021; Johansson & Nilsson, 2021). Additionally, education and training are essential to overcoming resistance and ensuring that construction professionals have the knowledge and skills needed to effectively work with EFC (Miller et al., 2018; Lindblad & Eriksson, 2020). By fostering a culture of innovation and sustainability, Sweden's construction sector can transition toward a more environmentally responsible future (Gustavsson et al., 2019).

2. Method of the Study

This study utilizes secondary data and expert opinions to explore the adoption of environmentally friendly concrete (EFC) in Sweden. A comprehensive literature review was first conducted to identify the critical technical, economic, and regulatory factors influencing EFC adoption. The review provided a detailed understanding of the challenges and opportunities related to EFC, serving as the foundation for the development of the survey instrument.

To assess industry perspectives, a structured survey was created targeting construction firms across Sweden. The survey aimed to measure the importance of various criteria influencing companies' decisions to adopt EFC. The 18 criteria included in the survey addressed key aspects of EFC adoption, such as long-term durability, cost-effectiveness, compliance with industry standards, environmental impact, and ease of integration into existing construction processes. These criteria were designed to capture both the technical and economic considerations that construction firms must evaluate when deciding whether to incorporate EFC into their operations.

The survey was distributed to a broad sample of construction firms, ranging from small to large enterprises, to gather a representative set of responses. The questions were designed to assess both the barriers to and incentives for using EFC, as well as the firms' awareness of its environmental benefits and their readiness to integrate it into their projects. Expert opinions were also sought to supplement the survey data, providing deeper insights into the regulatory, technical, and market factors that influence EFC adoption in Sweden.

By combining the findings from the literature review and the survey results, the study aimed to develop a comprehensive understanding of the current state of EFC adoption in Sweden and identify the main factors that either hinder or facilitate its integration into the Swedish construction industry.

3. What Experts Opine

Research on sustainable concrete, often referred to as green concrete, has explored various strategies to mitigate the environmental impact of cement-based materials. One prevalent method is the substitution of cement with industrial by-products such as fly ash, ground granulated blast-furnace slag (GGBS), and silica fume. These supplementary cementitious materials (SCMs) not only improve concrete's strength and durability but also significantly reduce carbon dioxide emissions associated with traditional cement production (Scrivener et al., 2018). For example, fly ash, a by-product of coal combustion, can replace up to 30% of cement without compromising concrete's mechanical properties, reducing CO2 emissions by 20-30% (Mehta, 2001). Similarly, GGBS, a by-product of the steel industry, enhances concrete's long-term durability while cutting its carbon footprint by up to 50% (Malhotra, 2002).

Another approach involves the use of recycled concrete aggregates (RCA) sourced from demolished structures. RCA helps minimize construction waste and the need for virgin materials, promoting a more circular economy in construction (Tam et al., 2018). Studies have shown that RCA can replace up to 100% of natural aggregates in non-structural applications with minimal impact on performance (Oikonomou, 2005). However, its use in structural applications remains limited due to concerns about quality variability and potential reductions in strength (Pacheco-Torgal et al., 2013).

In addition to these traditional methods, advanced concrete formulations incorporating bio-based materials, such as hempcrete and algae-based binders, are being explored for their potential to lower carbon footprints. Hempcrete, made from hemp fibers and lime, offers excellent thermal insulation and a negative carbon footprint due to hemp's carbon sequestration abilities (Arrigoni et al., 2017). Likewise, algae-based binders, which use microalgae to produce bio-cement, offer a promising alternative to conventional cement by capturing CO2 during production (Jonkers et al., 2010). These innovative materials represent a shift toward bio-inspired, carbon-neutral concrete technologies.

Despite the growing evidence supporting the environmental benefits of environmentally friendly concrete (EFC), its adoption in Sweden remains slow. Key barriers include industry resistance to change, lack of knowledge dissemination, and concerns about the long-term performance of alternative materials (Lindblad & Eriksson, 2020). Construction companies often prioritize proven, standardized materials to ensure compliance with regulations and structural integrity, making them reluctant to adopt new formulations without extensive testing (Hansen et al., 2019). A survey of Swedish construction firms found that 70% of respondents were concerned about the long-term durability of EFC, especially in harsh climatic conditions (Johansson & Nilsson, 2021).

Furthermore, the absence of standardized testing protocols for EFC complicates its adoption. While traditional concrete has established performance benchmarks, the variability in EFC formulations—due to differences in local material availability and processing—makes it difficult to develop universal standards (Taylor, 2020). This uncertainty leads to increased costs and delays, deterring firms from embracing EFC (Gursel et al., 2016).

To address these challenges, collaboration between researchers and policymakers is essential to develop comprehensive guidelines and standards for EFC. The European Committee for Standardization (CEN) has initiated efforts to create new standards for sustainable construction materials, including EFC, ensuring their performance and safety (Boverket, 2021). Additionally, pilot projects and case studies that demonstrate the successful use of EFC in real-world applications can help build confidence among industry stakeholders. For example, the HS2 high-speed rail project in the UK has shown that EFC can reduce carbon emissions by up to 50% compared to traditional concrete (Scrivener et al., 2018).

Education and training programs are also crucial for overcoming resistance to EFC. Incorporating EFC into engineering and architecture curricula, as well as offering ongoing training for industry professionals, can foster a culture of innovation and sustainability in the construction sector (Gustavsson et al., 2019). The Swedish Construction Federation has already launched workshops and seminars to educate contractors and engineers about the benefits and applications of EFC (Lindblad & Eriksson, 2020).

4. Concerns and the Concrete

The adoption of environmentally friendly concrete (EFC) in Sweden hinges on several technical, economic, and regulatory criteria that influence the decisions of construction companies. The survey developed for this study sought to evaluate the importance of these factors, which were derived from a comprehensive literature review. Among the key criteria considered were the strength, long-term properties, and durability of EFC, as well as its casting properties and applicability in harsh environments. Additionally, the survey examined more market-oriented factors such as purchase price, the availability of prefabricated elements, and the existence of relevant standards and policies. By identifying these criteria, the survey aimed to understand the various considerations that shape the decision-making process of construction firms in Sweden when it comes to adopting EFC.

The findings of the survey revealed that the technical properties of EFC were deemed the most important by respondents. Long-term properties and durability, in particular, received the highest ratings, indicating that Swedish construction companies prioritize the safety, reliability, and performance of the materials they use. This emphasis on technical performance aligns with the results from several studies, which show that EFC can offer equivalent or superior strength compared to traditional ordinary Portland cement-based concrete (OCBC), with some EFC formulations even achieving faster strength development. The durability of EFC, particularly in harsh environments, was also highlighted as crucial for its adoption in certain projects. The ability of fly ash-based EFC to resist chloride penetration in saltwater environments is one example of how this material can outperform conventional concrete in specific conditions.

Interestingly, while technical factors took precedence, economic and regulatory considerations were viewed as less critical. For instance, although subsidies and carbon taxes were included in the survey, they did not emerge as major drivers for the adoption of EFC. This suggests that construction companies, while cognizant of the environmental impact of their operations, place a higher value on the performance and durability of the materials they use rather than financial incentives or government regulations. The existence of standards for EFC use, however, was regarded as a key enabler, providing firms with the confidence that the material meets safety and performance requirements.

Furthermore, the survey results revealed some variation in the importance of certain criteria depending on the specific type of project. For example, the availability of prefabricated EFC elements was considered essential, as prefabrication can streamline construction processes and reduce labor costs. However, this criterion received more mixed responses, suggesting that access to prefabricated elements is more relevant for certain types of construction projects than others. Similarly, the application of EFC in harsh environments was prioritized for specific uses, indicating that the material's advantages in certain conditions are not universally applicable.

The survey also included an open-ended section where respondents could add additional criteria not covered in the survey. This allowed for valuable insights into other factors influencing the decision-making process. For instance, some respondents emphasized the importance of drying time and short-term strength, especially in the context of demoulding time during construction. These concerns are critical for projects that require fast turnaround times and highlight the complexity of evaluating EFC, which, like all materials, must meet both short-term and long-term performance requirements.

5. Conclusion

Swedish construction companies are open to adopting environmentally friendly concrete (EFC), provided it meets key technical and safety requirements. While financial incentives and regulations play a supporting role, the primary drivers for adoption are EFC's performance, durability, and reliability. The study highlights the importance of long-term properties and established standards for EFC's use. The positive attitude toward EFC suggests that overcoming barriers will require further research, field testing, and the development of robust standards. The criteria identified in this study may be applicable to other countries and construction sectors.

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