The Feasibility of Coating PH-X with BESE-Reef Paste for Oyster Reef Restoration

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BESE-Products is a Dutch company specialising in solutions that support the restoration of ecosystems. BESE uses materials that are biodegradable and sourced from waste streams. This assignment was offered to explore the potential of integrating a novel biopolymer composite, PH-X, into their product line. The restoration of European Flat Oyster reefs in the North Sea, particularly within offshore windfarms, represents a significant opportunity to enhance marine biodiversity and support sustainable ecosystems. This research explored the feasibility of using PH-X, a biodegradable biopolymer biomass composite, as a base material coated with BESE-reef paste to create structures that could facilitate oyster reef rehabilitation. The project was driven by a material-driven design approach, focusing on the inherent properties and production processes of PH-X and BESE-reef paste to evaluate the feasibility of developing a solution that is both environmentally sustainable and technically viable in the challenging conditions of the North Sea. The focus of the research based on the iterative design circle and a material driven design approach can be seen in Figure 1.

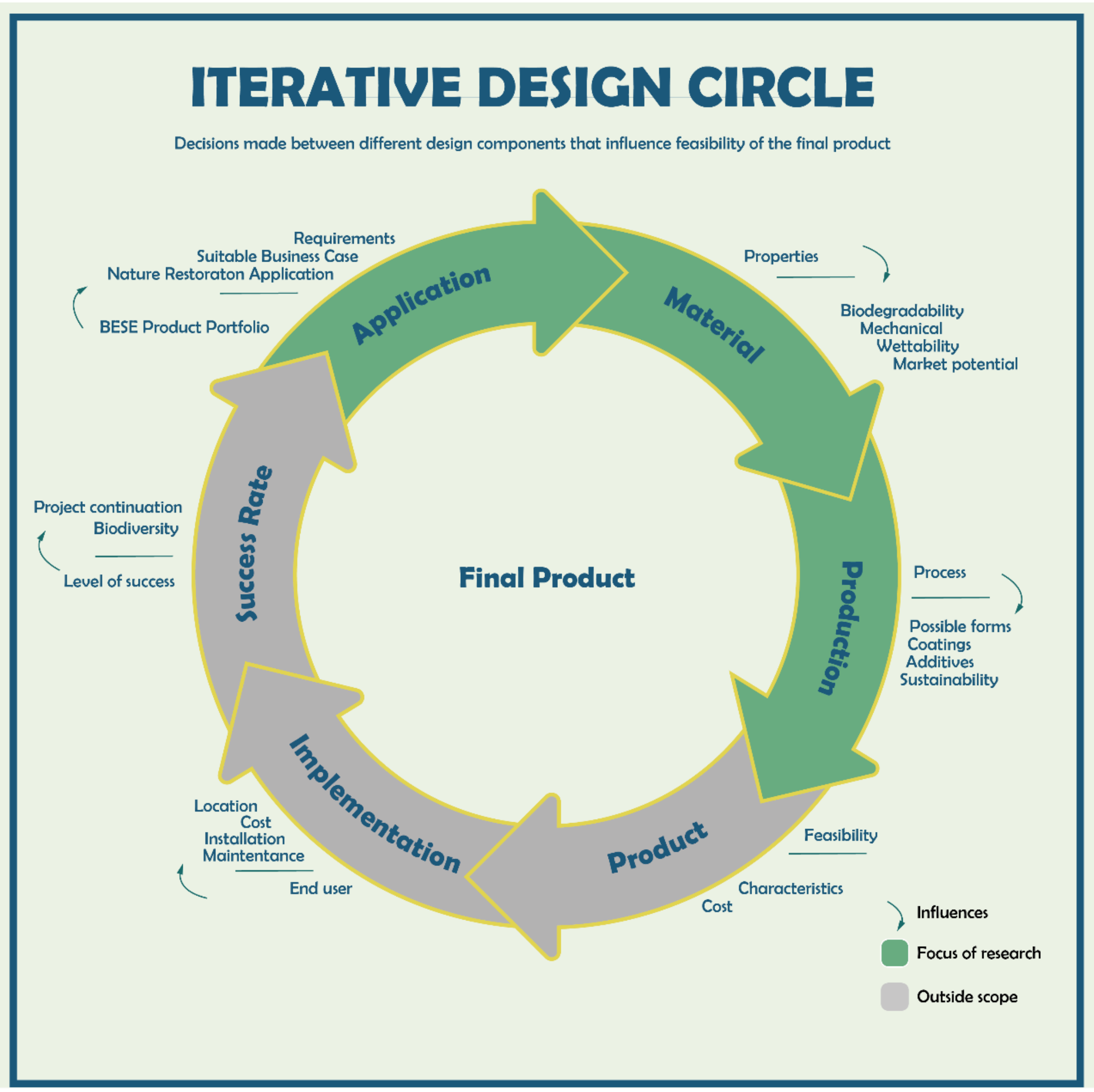

Figure 1: : Generalised iterative design circle in the context of BESE

PH-X is a composite material developed through the PRO-PHBV project. In waste water streams with high levels of organic material, a type of bacteria exists that consumes the material and synthesises PHBV (a biopolymer.) This bacteria is extracted and compression moulded, creating PH-X plates, a PHBV-rich biomass material containing both the PHBV and the bacteria within it. This material is designed to be a biodegradable alternative to traditional plastics, with particular potential in nature restoration applications. PH-X's unique composition includes both the biopolymer and the bacterial biomass, which simplifies production and enhances the material's potential by eliminating the need for costly filtration procedures (TUDelft AMS et al., 2022). BESE-reef paste, developed by BESE-Products, is a biodegradable material designed to attract and aid the settlement of the endangered European flat oyster, which plays a crucial role in marine ecosystems. The paste can be applied as a coating on various substrates, helping to create artificial reefs that support marine life (BESE Products, 2024).

The research's primary objective was to determine whether PH-X could serve as a robust skeleton material when coated with BESE-reef paste. This required a thorough investigation into the adhesion properties between the two materials. The North Sea's strong tidal currents and varying seabed conditions present unique challenges, necessitating materials that can withstand these harsh conditions while remaining stable over time (Rijksoverheid, 2022). Macroscale, microscale and chemical bonding strategies for improving adhesion between dissimilar materials were researched and applied to the assembly of materials. Lap shear tests were used to evaluate the shear stress resistance of the combination of mechanisms when applied. An example of the samples made for testing can be seen in Figure 2 and the equipment used for testing can be seen in Figure 3.

Figure 2: Samples designed for testing shear resistance of assembly

Figure 3: Lap shear test machine with a clamped sample

A significant challenge identified during the study was the swelling behaviour of PH-X when exposed to water, which creates shear stress at the interface that the reef paste cannot endure before it has fully cured. This issue leads to the failure of the adhesive bond between the materials, making the combination unsuitable for the intended application in offshore windfarms. Despite successfully identifying an optimal combination of natural reinforcement additives to the reef paste and macroscale mechanical interlocking mechanisms to enhance adhesion, the shear stresses were too great for the adhesive bond to maintain structural integrity to an adequate extent.

Despite these challenges, the research provided valuable insights that will inform future product development. A key outcome was the creation of a framework designed to guide BESE in developing and evaluating the feasibility of new products using novel materials like PH-X. This framework emphasizes iterative testing, early identification of potential material issues, and the refinement of material combinations before large-scale implementation. By following this structured approach, BESE can avoid risks associated with transitioning innovative materials from research to market-ready products. Furthermore, it identifies the go/no-go point in the process at which BESE should decide whether further investment into research and development is worth the potential outcome given the current stage of development of the novel material. The framework can be seen in Figure 4.

Although PH-X in its current form may not be suitable for oyster reef restoration in offshore windfarms, the research underscores the potential for further innovation and development. By leveraging the findings around natural additives and interlocking mechanisms, BESE can explore alternative applications, such as mussel reef restoration. The framework established ensures that BESE is well prepared to continue work in developing sustainable, circular solutions for nature restoration using novel materials.

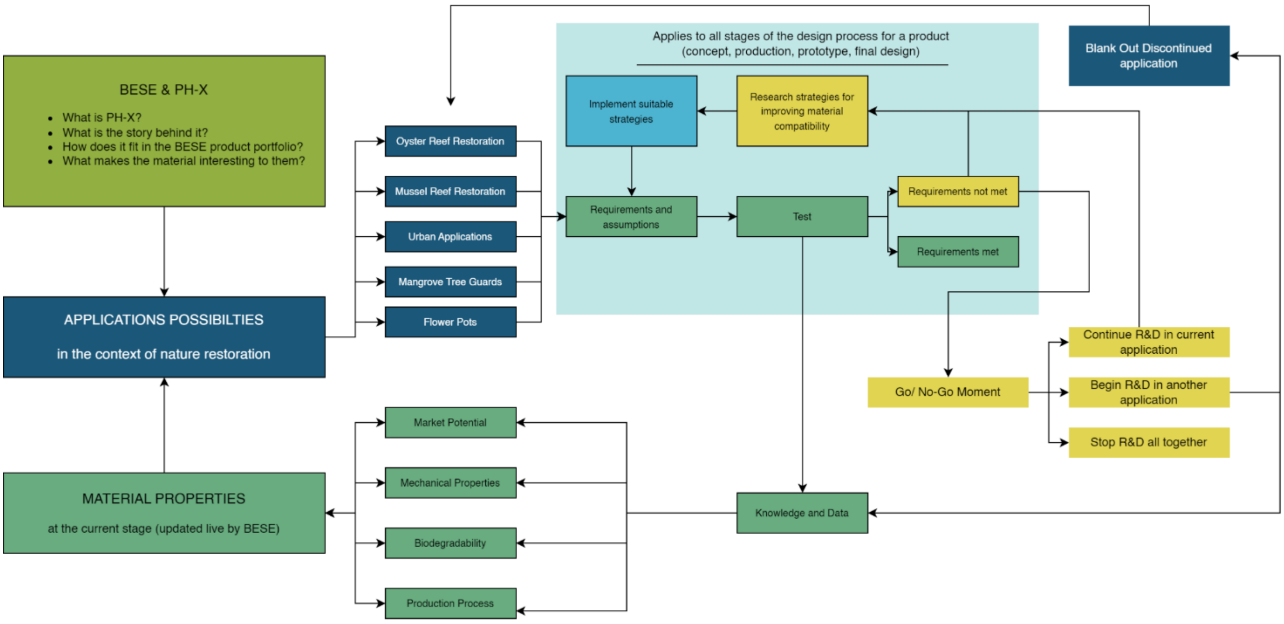

Figure 4: Framework for Evaluation of PH-X Feasibility for Product Development in the Context of BESE