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Development of an Innovative and Non-Corrosive Pickling Solution For Glass Fiber Reinforced Concrete (GFRC) Panels

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Abstract

Esthetic effects can be achieved by using color pigments or decorative stones in special concretes such as glass fiber reinforced concrete (GFRC). These special materials transform concrete from a purely structural element into a means of esthetic expression. Colored pigments allow concrete to be customized in a variety of colour palettes, moving away from grey tones, while decorative stones add textural richness and visual variety to the surface. The use of chemical solutions to remove the surface of concrete to reveal aggregates is called 'etching' or 'surfacing'. The 'Non-Corrosive Concrete Surface Abrasive Solution, developed in collaboration with industry and academia and registered with the Turkish Patent Institute under application number 2023/019603, reacts with alkaline cement to neutralize the top layer of the concrete surface and properly expose the sand/aggregate matrix beneath the concrete shell. The domestic and national chemical product developed because of this collaboration is one of the priority products published by the General Directorate for Strategic Research and Productivity of the Ministry of Industry and Technology. The solution was optimized with the support of the KOSGEB R&D and Innovation Project, and preliminary trials of the solution have been successfully completed. Companies producing GFRCs, which use specialty chemicals imported from abroad, have ended their foreign dependence on this domestic product. Our country's ability to produce solutions based on its own resources has been strengthened, and an important step has been taken towards a sustainable future in the GFRC sector. Owing to the corrosion inhibitors contained in the product, the corrosion of the steel-frame elements used in the assembly of GFRC facade elements is prevented, which is the most important innovation in this field.

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1 INTRODUCTION

GFRC facade elements are the exterior-visible components of buildings and special structures. These structural elements are architectural concretes with significant esthetic value. Architectural concretes are produced using specialized materials, special mold designs and unique surface treatments [1].

Existing concrete surfaces are typically plain and monochromatic. However, by incorporating color pigments or decorative stones into specialized concretes such as GFRC, visually distinctive and esthetically pleasing designs can be achieved. These materials transform concrete from a mere structural component to a medium for artistic expression (Figure 2).

Figure 1. Application of the GRFC facade

Figure 2. Acid treated GFRC surface samples

Surface treatments for GFRC facade panels include sandblasting, pickling, honing, and the creation of surface-specific textures using specific chemicals. Panels made from concrete mortar with carefully selected, graded aggregates are surface treated after removal from the mold. During the pickling process, the top layer of the concrete is abraded to a certain depth. The chemical composition and environmental safety of the acid used in this process are critical. The special acid initiates a chemical reaction with the concrete surface, dissolving the cement matrix and exposing the aggregates. This method enhances the appearance of facades with a decorative and esthetically pleasing appearance [2-6].

This study discusses the application method of a domestic product specially developed for pickling surface treatment of GFRC panels and its advantages over imported product. The aim is to prevent the corrosion of steel materials used in the assembly of GFRC facade elements. Figure 3 shows the corrosion of the steel hooks that connect the GFRC panels to the steel frame. It has been scientifically proven that corrosion reduces the load-bearing capacity, as detailed in various studies [7].

Particularly for concrete panels with an average weight of 400 kg, loss of adhesion due to corrosion increases the potential for the panels to separate from the building surface. As shown in Figures 4 and 5, given the weight of these panels, loss of adhesion is a serious safety risk. If such an event occurs, the consequences can be irreparable. This situation can compromise the structural safety of buildings, resulting in both financial losses and significant risks to human safety [8].

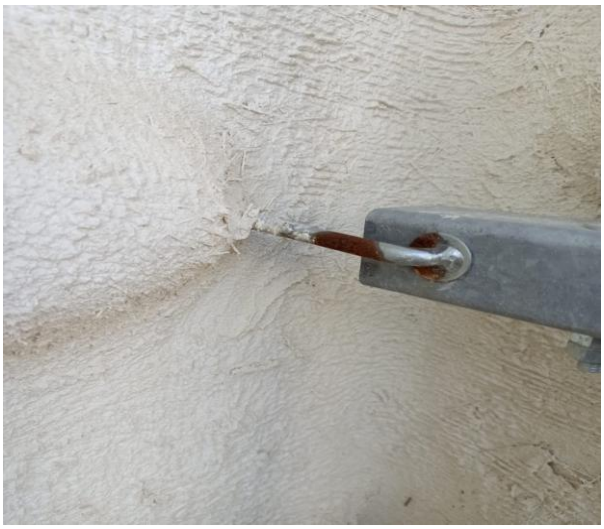

Figure 3. Corrosion at the joint between the GFRC panel and steel frame

Figure 4. Metal anchors behind the GFRC panel

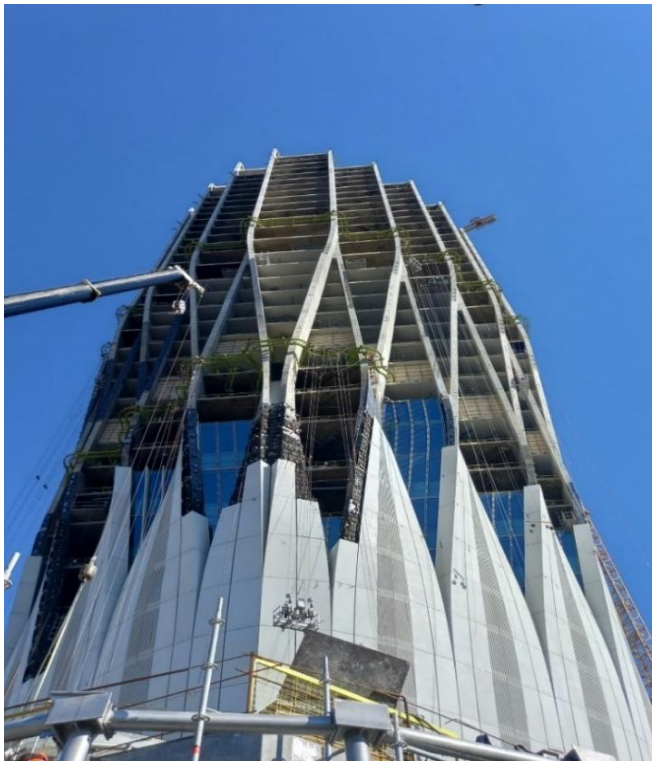

Figure 5. Installation of the GFRC panels on the building exoskeleton

There are various methods for protecting steel components from the corrosive effects of chemical products. If an acidic chemical comes into contact with steel elements during surface treatment, corrosion will start and accelerate in the atmospheric environment. In this study, for the first time, corrosion inhibitors were used to protect steel anchorage elements from acidic effects while the surfaces of GFRC panels were degraded with the discussed and patented chemical product.

2 MATERIALS AND METHODS

2.1 Preparation of the corrosion inhibitor solution

A corrosion inhibitor is a chemical substance that effectively reduces the corrosion of metal in a corrosive environment. There are organic or inorganic corrosion inhibitors which can provide highly effective protection even at low concentrations.
Metal corrosion inhibitors are used in the range of 0.01-3% by mass based on the total amount of concrete etch composition [9,10]. Concentrations in this range did not adversely affect the etching efficiency of the solution while protecting the metal surfaces from corrosion. As a result, the desired abrasion thickness on the surface of the GFRC panels is achieved, while minimizing corrosion on the metal surfaces bonded to the concrete [11].

2.2 Application of the proposed solution to GFRC panels

GFRC facade panels high flexural strength due to their glass fiber reinforced concrete mixes. The production of GFRC facade panels requires specialist skills and experience from the architectural design stage through the installation process. Figure 6 shows the GFRC panel element that was produced during the project. After casting the panels in special molds, the demolding and surface treatment steps are carried out with great care. The application of the acid solution and the steps of application to the target surface are followed in order to achieve the same quality and appearance results for each panel element.

The acid solution was applied to the GFRC panels are as follows;
1) Thoroughly wet the surface of the material to be treated with the acid solution. Use a sponge or brush to remove excess water from the surface.
2) Mix the acid solution in a container before application. Remove any sediment from the bottom of the container.
3) The amount of acid to be used was calculated according to the size of the panel, and the acid solution was transferred from the acid container to a calibrated container.

4) Apply the acid solution evenly to the surface using a soft brush that does not scratch the surface (Figure 7).
5) Acid solution causes a tingling sensation on the surface. This indicates that the reaction on the surface continues. Wait for the tingling to stop before brushing the surface (Figure 8).
6) Brush the surface of the panel (Figure 9). When the desired surface roughness and aggregate visibility are achieved, the brushing process is stopped. The panel surface was rinsed with water and the solution application is completed (Figure 10).

Figure 6. Front and back sides of the GFRC panel

Figure 7. Application of the acid solution to the GRFC panel surface

Figure 8. Keeping the solution on the GRFC panel surface

Figure 9. Brushing the GRFC panel surface with the chemical solution

Figure 10. Obtaining and rinsing the surface

The desired aggregates are expected to appear on the final surface obtained. In this context, the pickling process is repeated if necessary.

This study discusses the advantages of locally developed, patented chemical product over the imported solution. In addition to overcoming the challenges of logistics, sourcing, and price volatility, the product has been effective in solving the undesirable problem of "chemical-electrochemical corrosion" that occurs during the acid etching process of the anchor elements used in GFRC panels. The corrosion inhibitor forms a protective film on the fasteners, reducing the rate at which the metal reacts with acid.

3 CONCLUSION

This study presents a national and innovative chemical product that prevents the negative effects of acidic chemicals used in the surface treatment of GRFC panels on steel anchorage elements. The developed solution containing a corrosion inhibitor effectively prevented the corrosion of steel elements during the pickling process and enhanced their long-term durability. The results of this study show that the corrosion inhibitor provides the desired decorative appearance while protecting the steel elements without adversely affecting the etching efficiency of the concrete surface. This feature provides significant benefits in terms of both esthetics and structural integrity. This domestically developed product also makes a significant contribution to the efficient use of national resources and to economic sustainability by reducing dependence on imported chemicals. This study provides a reliable and cost-effective alternative for GRFC manufacturers and demonstrates that a sustainable future is possible with domestic solutions in this sector. The high export potential of the product means that it will be in demand not only in the domestic market but also internationally. This indicates that our project will make a positive contribution not only to the local economy but also to the trading potential of the entire country. Future scientific work may focus on evaluating the long-term performance of this solution under different environmental conditions and examining its effects on different types of concrete. In this context, it would be beneficial to extend and optimize the areas of application of this newly invented product.

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Author Contributions

Husnu GERENGI: Conceptualization, Methodology, Validation, Project Administration, Writing – Original Draft, Writing – Review & Editing.
Muhammed MARASLI: Resources, Data Curation, Funding Acquisition, Writing – Original Draft, Writing – Review & Editing.
Kader COSKUN: Investigation, Supervision, Formal Analysis, Visualization, Writing – Original Draft, Writing – Review & Editing.

All authors read and approved the final manuscript.

Conflict of interest

No conflict of interest was declared by the authors.

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