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Geopolymer Column Wrapping

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16. Abstract

This report deals with the use of an inorganic-polymer coating for the protection and strengthening of transportation infrastructures. The constituents of the coating include nano-silicates and other nano-size activators and fillers. The demonstration project consisted of wrapping of columns with carbon fibers and inorganic-polymer, which is located in Maryland State. Details of the projects and the basic study conducted for the evaluation of durability of the coating are presented.

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Introduction
Surface deterioration of concrete is becoming one of the major problems for durability of concrete structures. The surface deteriorations could develop into structural problems, especially in reinforced concrete structural elements. The most efficient way to reduce this deterioration is to prevent the liquid ingress into concrete, thus preventing the ingress of chemicals such as chloride from salts and subsequent deterioration. The coating used to protect the surface should allow the concrete to breath. Otherwise, the coating will delaminate due to liquid collection at the interface. Therefore, a strong need exists for the development of an inorganic coating, which is less permeable than concrete and will allow the concrete to breath.

The results of the previous research have shown that the inorganic polymer coating is a viable alternative to organic polymer and polymer modified cement coatings [1]. The primary difference is the compatibility of the new coating with common construction materials such as concrete, concrete bricks including hollow core blocks, clay bricks, steel and timber. The constituent materials of the coating chemically react with the concrete because Portland cement used in concrete is a calcium alumino-silicate system where as the cement in the coating is potassium alumino-silicate. Any free hydroxide in concrete will react with silica in the coating and vice versa[2]. Since the coating contain submicron and nano particles they penetrate both timber and clay-brick surfaces. Small amounts of rust present in steel act as activators for the coating, thus improving the bond.

Absence of bond failure between the matrix and the parent surface in a large number of tests involving both strengthening and coating confirms the compatibility and excellent bond. Since the coating allows for release of any vapor pressure from the parent surface, blistering is eliminated. The long term durability of both the coating and the interface provides the primary motivation for the demonstration projects. Self cleaning property of the coating system will provide a giant step forward for this relatively new material. The fact that the coating can withstand up to 1000˚C provides the motivation for creating systems that can be used in critical locations such as staircase enclosures [3]. This high temperature property can also be effectively useful in buildings which have been exposed to biological agents such as anthrax, so it can be eliminated from the building interior by simply heating the entire building to a threshold temperature that is needed to kill these agents.

Background Information

NJDOT in cooperation with Rutgers, The State University of New Jersey have developed an inorganic coating material that can be used as a protective coating. This coating material is about two orders of magnitude less permeable than concrete but allows for release of vapor pressure or allows concrete to breath. The coating also provides a glassy surface to which organic paints do not stick. The basic features of this material are as follows.

The coating formulation, generically called an inorganic matrix, is a polymer like material that is being evaluated for applications in aircrafts and civil infrastructure. Originally it was developed for use in aircraft structures and modified for use as a coating material and adhesive for brick, concrete, wood, and steel. The resin is prepared by mixing a liquid component with silica powder. Fillers and hardening agents can be added to the powder component. The two components can be mixed to the consistency of paint. The matrix is water based; consequently tools and spills can be cleaned with water. All of the components are nontoxic and no fumes are emitted during mixing or curing. The matrix bonds well with carbon and glass fiber reinforcements.

Common application procedures such as brushing and spraying can be used. The product was successfully used to coat transportation structures by brush and a sprayer in New Jersey and Rhode Island.

Demonstration Application: Strengthening

The objectives of this application were to wrap two columns supporting a bridge on Route 40, Hagerstown, Maryland with Geopolymer/carbon fibers to form a water and salt barrier; to coat the carbon fibers with a colored inorganic nano coating to preserve the appearance to match the preexisting epoxy wrapped columns and monitor the Geopolymer and epoxy wrapped columns for their respective bonding to the concrete substrate and the salt content in the protected concrete.

Step1: Material selection and formulation development for approval

The 3k carbon tape was picked. The carbon tape is available in 50 ft. long roll and 4 in. width. Two different sets of Geopolymer matrices were prepared: the first set is the basic Geopolymer matrix to keep the tapes in place; the second set is a modified Geopolymer formulation using pigments to obtain a creamy color. Small concrete cylinders were used to apply the carbon tape and coated with the modified matrix to simulate the field wrapping technique and to ensure the color resemblance.

Step2: Cleaning

The concrete surface was originally painted with an organic coating. In order to apply the wrapping this painting was removed and surface was cleaned. After that, the columns were washed and the scaffoldings were established. In spite of the cleaning, some sections were not completely cleaned Figure 1-a.

Figure 1 a) Column after cleaning b) Column wrapped with carbon tape

c) During final coating application d) Column after final coating

Step 3: Application

The first base coat was applied by the Rutgers team under the supervision of Professor Balaguru in corporation with the University of Maryland team under Professor Peter Chang supervision with the aid of commercially available foam rollers. Then, the carbon tape was applied simply by moving around the column circumference and it was hand-placed in place Figure 1-b. The columns were left to dry out for eighteen hours after protecting them with some polyethylene sheets from a heavy thunderstorm. The third step was to apply a top base coat for guaranteeing a complete fibers impregnation with the matrix. Subsequently, the final stage was to apply the coloring matrix coating with a very small time gap between the third and the final stages Figure 1-c and d.

Step 4: Monitoring

The performance of Geopolymer-based FRP and the epoxy-based FRP will be monitored for three years for their interface bonding on the concrete substrate and salt content by University of Maryland. The self cleaning and de-polluting properties will be investigated by Rutgers University.

Summary

The field demonstration project presented in this report and other applications carried out in New Jersey and Rhode Island show that the inorganic-polymer coating can be applied with and without continuous fiber reinforcement. The system is easy to work with and the applications carried out with paint brushes or rollers.

The oldest application is about 7 years old and is performing well. The coated surfaces have been exposed to a number of snow storms, freeze thaw cycles, salts used to melt snow and abrasion by snow removing equipment.

The self cleaning properties and de-polluting properties are being evaluated under the sponsorship of the National Science Foundation of the Unites States of America.

References

[1] Nazier M., “Evaluation of high strength composites and new construction techniques for their effective use” Ph.D. Thesis, Rutgers University, 2005.

[2] Garon R.J.,”Effectiveness of high strength composites as structural and protective coatings for structural elements” Ph.D. Thesis, Rutgers University, 2000.

[3] Lyon, R.E. et al (1997), "Fire Resistant Aluminosilicate Composites," Fire and Materials, John Wiley & Sons, Vol. 21, pp. 67-73.