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Relining of Domestic Piping System with Rubber Filled Epoxy and Reinforced Polyester Composites

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***Abstract*—**Pipe failure and leakage is a problematic issue and the traditional solution of replacing the pipes is costly and time consuming. Rehabilitation by relining materials based on polymer composites is an alternative solution towards the degradation problem of the old piping. This paper provides a brief summary of advances in technology, methods and materials for relining as well as a summary of the degradation analyses of the two main composite materials used for relining, rubber filled epoxy and reinforced polyester baltoflake when they are exposed in deionized water and elevated temperature up to 80°C for a duration of 2-14 months in the laboratory.

***Keywords*—**Composite, Epoxy, Polyester, Pipes, Relining.

I. Introduction

THE reason of rehabilitation techniques is to maintain performance and extend service life to keep the sewerage functioning at an acceptable level. Rehabilitation may include internal coating, sealants, and lining [1]. One common example of rehabilitation by lining for sewage is the CIPP (cured in place) liners which are used mainly in industry and public pipe systems. Good practices for CIPP installation include adequate record keeping and post rehabilitation camera inspections to confirm the fit and finish of the cured liner [2]. It is estimated that about 65,000 km of CIPP liners have been installed worldwide. It is by far the leading method for rehabilitating gravity sewers [1]. This method is similar to the flexible sleeve technique that is a common way of applying relining in sewage systems. After applying the relining material, no source of heat is used for curing of the applied material inside the houses and the material is thus cured in ambient temperature.

Water Research Center (WRC, UK) proposes a sandwich of lining for a relining layer consisting of lining material, grout and existing sewer [3] while in modern relining application in Sweden, no grout is used between lining material and the host pipe [4].

The most common matrix resins for the relining applications are unsaturated polyester resin and epoxy resins. The unsaturated polyester used in the spray method is reinforced by baltoflake and the epoxy resin for brush-on technique is modified with nitrile rubber. In the third main method or flexible sleeve method, it is also epoxy resin which is used by penetration to a polyester/polyurethane textile fabric. Polyester resin and spray-on relining is widely used in Nordic countries in Europe for the small-diameter water pipe rehabilitation. It consists of unsaturated polyester resin which is reinforced with glass flake for providing high values of stiffness and strength and its solvent is vinyl toluene. The second content is the curing agent, a peroxide. The proposed thickness by the resin manufacturer is three layers of 900-1100 μm each [5].

It is possible to apply the resin and the hardener after mixing with an ordinary airless spray application which works by pumping paint at a high pressure, through a hole in the spray gun tip. The tip is designed to break up the paint evenly into a fan-shaped spray pattern of small droplets or a 2-comp airless spray which the resin and hardener are mixed right before application. Relining companies which use this technique allow a customer the possibility of using the water pipe after one day. The brush on method with epoxy uses a type of epoxy which is modified with Nitrile Butadiene Rubber. This modification gives an elastic property to the material. In the brush-on technique, a two components epoxy material is applied, the epoxy resin which is used is often a Bisphenol A with a urethane amine hardener. Epoxy resin is usually formed from reacting epichlorhydrin with Bisphenol A to form diglycidyl ethers of Bisphenol A (DGBA). This is commonly referred to epoxy functionality [6], [7]. Liquid epoxy resins are converted through these reactive epoxy sites into insoluble and infusible solids. The simplest possible epoxy resin derived from the reaction of Bisphenol A and epichlorohydrin is (2, 2-bis [4-(2'3' epoxy) phenyl] propane), commonly called the diglycidyl ether of Bisphenol A (DGEBA) [8]. Impregnated fiber is the other major technique which uses a prefabricated polyester textile to be impregnated by a two component epoxy resin. The thickness of the flexible sleeve liner inside the old pipe depends on the thickness and diameter of the old piping system. The prefabricated polyester textile is coated with a polymeric layer, mainly polyurethane for wear protection. The epoxy resin is impregnated to the textile by roller- impregnation process and installation before material is cured.

II. Investigation of Relining Composites after Exposure to Elevated Temperature and Water

A. Material Preparation

For preparing the polyester resin based samples, a commercially available relining material, based on a polyester resin dissolved in vinyl toluene and filled with glass flakes and filler was used (Jotun's Baltoflake Proline system). The material was mixed with 1.5 vol% of peroxide (Norpol

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peroxide 13) at room temperature (22°C) and a 1 mm thick layer was obtained by spreading the material on a glass plate covered with a film using an applicator and two distance pieces to control the thickness. The film was cured in room temperature. After one and two hours the second and third layer were applied in a similar way, respectively. The material was then stored at room temperature 22°C for two weeks before starting with the exposure experiments. Sheets of the material with dimension of 10 X 10 cm were placed in plastic jars, then filled with deionized water and placed in the ventilated oven at 40°C, 60°C and 80°C, (the container for sheets exposed to water at 22°C was left in the room temperature). After two months material was taken out for evaluation. To dry the sheets, they were placed in a ventilated oven at 40°C and the weight was measured in different periods of time until reaching the equilibrium. For preparing samples of epoxy modified with rubber, a commercially available relining material (Zel-Aaren Innovation Sweden) based on a two component thixotropic epoxy resin modified with rubber was used. The main component (Elasto-Liner component A) was mixed with the hardener (Elasto-Liner component B) at room temperature (22°C) and a 2 mm thick layer was obtained by spreading the material on a Teflon based glass plate using an applicator. The film was cured in room temperature. The material was then stored at room temperature 22°C for two weeks before starting with the exposure experiments. Sheets of the material with dimension of 10 X 10 cm were placed in plastic jars, then filled with deionized water and placed in the ventilated oven at 40°C, 60°C and 80°C, (the container for sheets exposed to water at 22°C was left in the room temperature). After two months material was taken out for evaluation. To dry the sheets, they were placed in the ventilated oven at 40°C and the weight was measured constantly in different periods of time until reaching the equilibrium.

B. Microscopy and Visual Inspection

Visual inspection and microscopy (light microscopy on grinded and stained samples) showed delamination of the material after exposure to the water at 80°C while sample exposed to the air at 80°C and other samples exposed to the water did not show any significant change (more pictures can be find in Appendix).

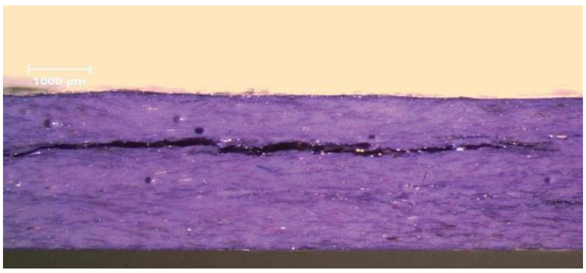

Fig. 1 Delamination of polyester baltoflake after 2 months exposure to deionized water in the highest temperature, 80°C after complete drying

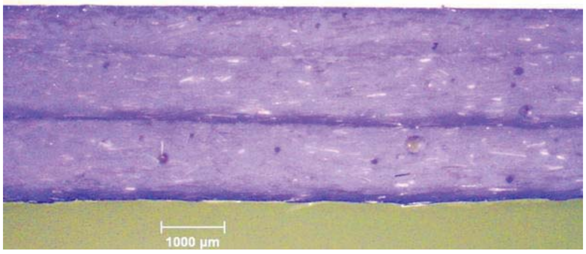

Fig. 2 Sample of Polyester baltoflake, the same material as in Fig. 1, exposed to only air at 80°C for 2 months

Fig. 1 shows delamination of the material after exposure to the water at 80°C, on the other hand, as it can be seen in Fig. 2, the same material when is exposed to only high temperature at 80 °C in dry conditions did not show any delamination under microscopy.

The delamination of the material exposed to water at 80°C seems to be mainly between different layers of the lining. None of the other samples exposed to the water at 22°C, 40°C and 60°C have shown a significant change under microscopy (Appendix).

Microscopy and visual inspection of the epoxy based material, with light microscopy on grinded and stained samples showed that material has changed significantly after exposure to water at 80°C. Sample exposed to air at 80°C showed less changes compared to the material exposed to water at the same temperature, samples exposed to water and air at lower temperatures did not show any significant change.

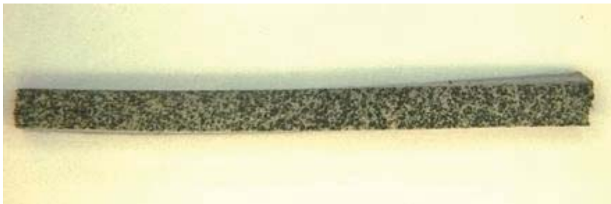

Fig. 3 A strip of the epoxy modified with rubber sample after 2 months exposure to deionized water at 80°C and complete drying

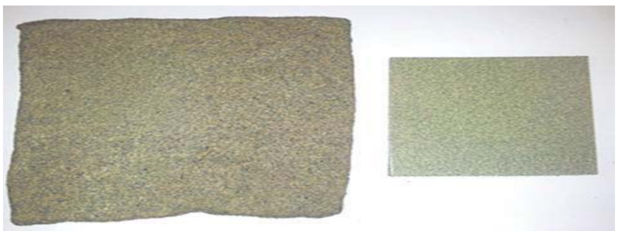

Fig. 4 Change in the dimension of an epoxy modified with rubber sample after 2 months exposure to deionized water at 80°C

As it can be seen from Figs. 3 and 4, epoxy material exposed to water at 80°C did not show the same degradation as the polyester based relining.

C. Water Sorption

Water sorption measurements for polyester material are carried out by immersion of samples with the dimension of 4 X 4cm in deionized water at different temperatures (22°C, 40°C, 60°C and 80°C). A typical sorption curve for a coupon exposed to the water at 60°C is shown below. This sample has reached the equilibrium after the maximum weight change of 4,43% and was taken out for the desorption measurements. The coupons which were exposed to the water at 80°C started to blister and delaminate after 7 weeks so the results for water absorption became different between different coupons exposed to water at 80°C.

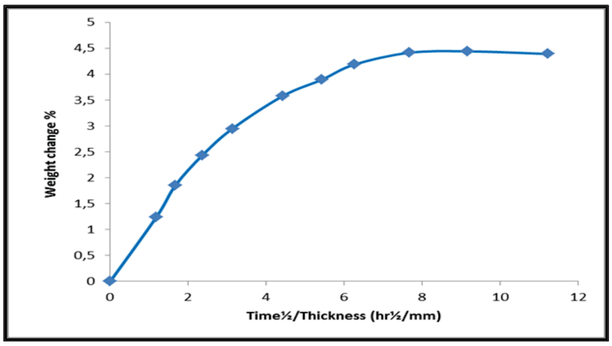

Fig. 5 A typical sorption curve for a coupon of polyester baltoflake immersed in water at 60°C

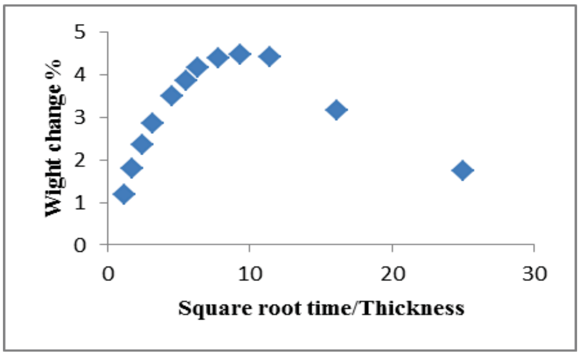

Fig. 6 Absorption curve for polyester baltoflake immersed in water at 60°C in oven during 14 months

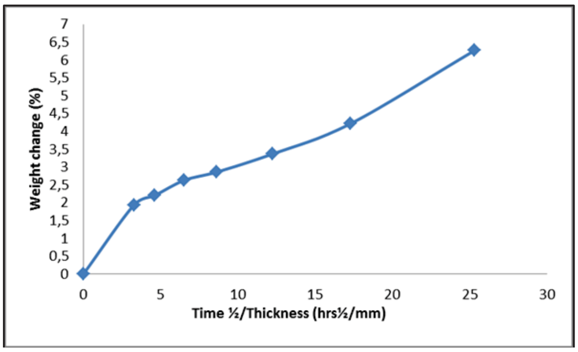

Fig. 7 A typical sorption curve for a coupon of epoxy modified with rubber immersed water at 60°C

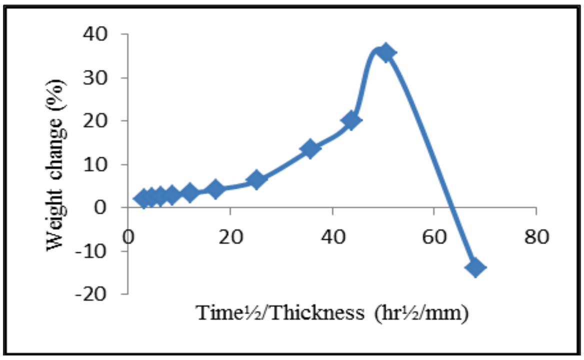

Fig. 8 Absorption curve for rubber filled epoxy immersed in water at 60°C in oven during 14 months

Water sorption measurements were carried out by immersion of material with the dimension of 4 X 4cm in deionized water at different temperatures (22°C, 40°C, 60°C and 80°C). None of the coupons exposed to water at elevated temperature reached the equilibrium and the water absorption was continuing. A typical sorption curve for a coupon exposed to the water at 60°C is shown below. This sample showed the weight change of 6,26% after 2 months.

In comparison of the two material types, it is noticeable that the epoxy material is absorbing water over a longer period of time and the water absorption is faster compared to the polyester based relining material.

III. Conclusion

Different experiments including microscopy and water absorption indicate that the lining material based on baltoflake reinforced polyester is very sensitive to exposure at high temperature, in this study 80°C. It was observed that the material has changed in properties significantly when high temperature is combined with water exposure. The coupons which were exposed to water at 80°C started to blister and delaminate after 7 weeks. However, the material did not show significant change in other conditions of exposure to the water and air in the elevated temperature from 22°C to 60°C within four months. Despite significant diminish in the stiffness of the material while tested under the wet condition, it regains the stiffness greatly after through drying. It should be noticed that the maximum average temperature inside the sewage system and consequently for relining material is assumed to be 40°C and the condition of several months constant water exposure at 80°C is comparatively extreme.

Relining material based on epoxy resin modified with rubber exposed to 22°C to 60°C in dry conditions, did not show any significant change, however different tests and visual observation showed that it has changed significantly after two months exposure in water at the highest temperature of 80°C. Epoxy based material absorbs water faster and in a longer period of time compared to the polyester material and did not reach equilibrium after two months -despite the polyester based material.

APPENDIX

Microscopy on relining material after exposure and drying shows that material is not sensitive while exposing to low temperature and only air but it is more sensitive while exposed to water in high temperature and shows delamination and degradation.

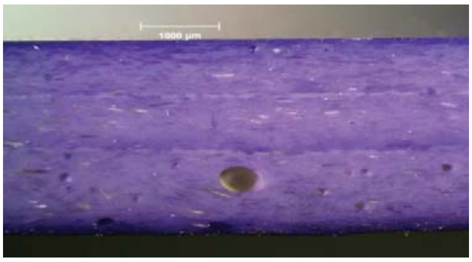

Fig. 9 Polyester baltoflake after 2 months immersed in water at 20°C

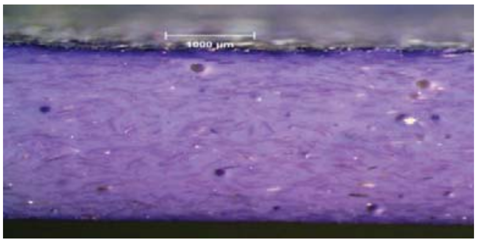

Fig. 10 Polyester baltoflake after 2 months immersed in water at 40°C

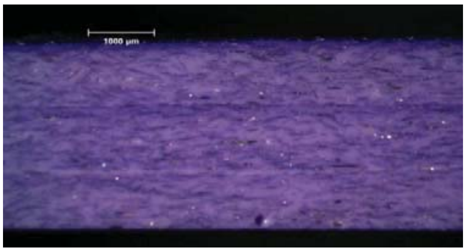

Fig. 11 Polyester baltoflake after 2 months immersed to water at 60°C

Fig. 12 Specimens prepared from polyester material immersed in water at 80°C for two months and after drying shows how delamination has happened along the edges

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