Repair and replacement of concrete pipes with carbon composites

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This paper describes the in-situ manufacturing of a carbon fibre pipeline by means of an epoxy resin infusion process followed by vacuum consolidation. The process uses as a lost mould the existing reinforced concrete pipe with steel core in poor condition, which serves for the cooling process of a nuclear power plant reactor. The carbon fibre pipeline, which is buried at a depth of 4 to 9 metres, is designed to provide by itself the required structural resistance and tightness, without considering the contribution of the existing pipeline.

Many plants in the industrial sector, not only nuclear power plants, but also petrochemical, chemical, electric generation, fluid transport, and other installations, are faced with a major challenge regarding the conservation and repair of the refrigeration systems used for the facilities or equipment, or even water treatment.

All these facilities are of similar age and, due to their long time in service, they suffer from the common corrosion and degradation problems of conventional materials such as carbon steel and reinforced concrete. Most of them are buried systems with great intervention and access difficulties, in addition to high operation costs.

Scope and description

Navec, Saertex and Henkel shared their knowledge and know-how in their respective disciplines to develop a safe, reliable, durable and innovative solution for in-situ manufacturing of a carbon fibre pipe using epoxy resin infusion and vacuum consolidation technology, a solution offering the most economical, fast and viable alternative. This innovative system was already used successfully in the rehabilitation of the tertiary cooling system of a nuclear power plant reactor in Spain, as well as in other facilities, using the existing pipe in poor condition as a lost mould. The new carbon fibre pipe – 800 mm diameter and 1,525 metres in length – is buried at a depth of 4 to 9 metres. It includes horizontal, vertical and inclined sections, and different elements such as elbows, tees, flanges and manholes.

Design, calculations and characterization tests

A finite element modelling of the complete system was carried out to define the carbon fibre laminate according to the design requirements, considering that the residual resistance of the existing pipe is zero, so all the loads are supported by the new carbon fibre pipe (permanent loads, own weight, fluid weight, internal pressure, terrain actions, traffic actions, thermal actions and seismic loads). Likewise, calculations were carried according to the ASME CASE N-589-1, ASME PCC-2 and ISO 24817 standards without considering the substrate contribution.

For each fitting or installation element (sections, elbows, tees, flanges and manholes), the configuration of each carbon fibre layer was designed, as well as the overlap and dimensions. Self-adhesive SAERfix carbon non-crimp fabrics from SAERTEX were used in this case. These tacky fabrics helped the workers for the lay-up, especially in the vertical sections of the existing pipe.

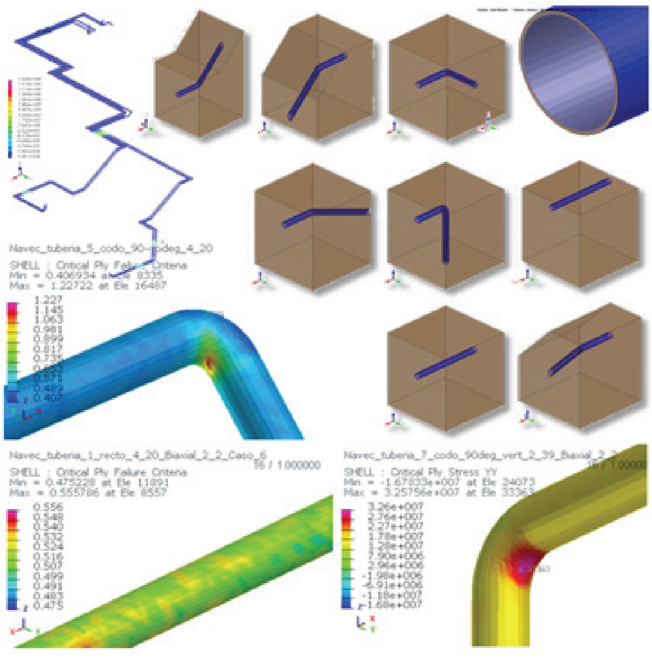

Fig. 1: Calculations and finite element modelling

Fig. 2: Installation of the SAERfix carbon non-crimp fabrics (self-adhesive)

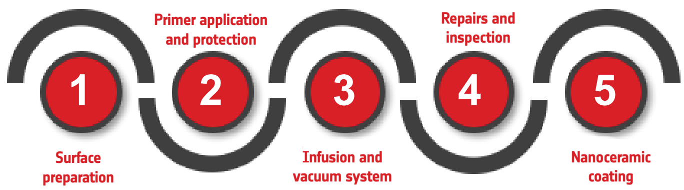

Fig. 3: The five process steps

Characterization tests were conducted by accredited external laboratories to verify the properties: tensile strength, compression, adhesion, glass transition temperature, hardness, thermal expansion coefficient and cathodic disbondment, among others. Likewise, real-scale tests were carried out to check the validity of the system developed and the feasibility of application by the workers, conducting hydraulic pressure tests on different samples.

The main challenge was to use an application methodology respectful of the workers' safety and the environment, avoiding the continuous exposition and inhalation of vapours coming from the materials used. This was made possible by the design of the infusion and vacuum system, transporting the epoxy resin with positive pressure in a closed system with localized vapour emission points with filters. This transport operation is carried out from the outside of the pipeline, being able to work 100 or 200 metres away, between the preparation area and the action area inside.

In-situ execution

The in-situ execution process, which lasted for 8 months, consisted of the following stages:

1. Surface preparation: abrasive blasting, surface reconstruction and deionized water cleaning.
2. Primer application and protection: using an epoxy resin and a peel-ply fabric to avoid contamination during the transit of workers inside the pipe.
3. Infusion and vacuum system: placement of the carbon fibre fabric and consumables for subsequent impregnation and vacuum consolidation control.
4. Removal of consumables, inspection and repairs if necessary.
5. Nanoceramic coating to waterproof the pipe and system start-up.

performance and the ability to

The process used 20,500 m² of carbon fabrics, 25,000 kg of epoxy resin, 13,200 valves, 28,150 m of vacuum tubing, 5,300 m² of vacuum infusion bags and 4,500 kg of nanoceramic coating.

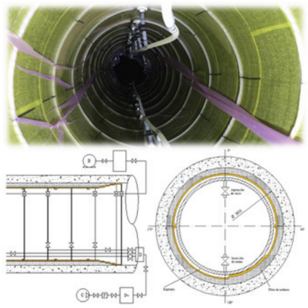

Fig. 4: Infusion and vacuum system, design and installation

Benefits and key advantages

a. Reliability. The carbon fibre pipeline was calculated, tested, and manufactured in-situ with a system that provides the best possible properties (reality vs. theory) without using ovens or autoclave systems.

b. Durability. The estimated lifetime is the next 40 years.

c. Safety. Safety was taken in consideration during the construction and installation phases, including for the workers and in terms of environmental impact. No excavations with risks for the nuclear power plant reactor were needed, avoiding process stops as well as technical and construction difficulties. The environmental impact of the solution was the minimum possible as no means of excavation or crane were required, avoiding the corresponding diesel consumption and CO2 emissions, as well as the vapours generated by conventional cutting and welding work.

d. Quickness. The whole process was up to 50% faster than traditional excavation repair works, minimizing the risk in case the existing concrete pipe was needed to cool the reactor (during the work).

e. Cost effectiveness. The cost was much lower than with traditional methods as there were no process stops, no deviations or modifications of other auxiliary services near the action area (gas pipelines, water, electrical wiring, fibre optics, telephone...), as well as no interference with the facility's operations.

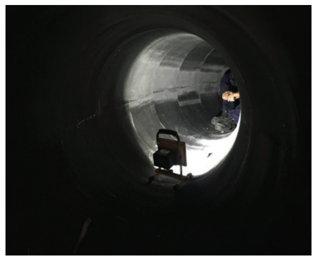

Fig. 5: The finished carbon fibre pipe before nanoceramic coating

This innovative system for the industrial sector is a versatile solution that can be applied to other substrates such as steel, inside or outside, and not only to pipes, but also equipment and pressure vessels in compliance with the ASME and ISO international standards. The greatest advantage is found in buried systems where logistical access difficulties and auxiliary means can be an impediment to repair or replacement processes.□

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