Waterproofing of Concrete Structures Intended for Storage and Transport of Liquids

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ABSTRACT : The use of membranes in the construction, renovation or repair of concrete structures designed to contain and transport liquids has become commonplace. Such facilities used for the storage and transport of water include reservoirs, tanks, water towers, treatment stations, aqueducts, canals, but also pools, pollution basins and stormwater spillways.This paper describes specific applications to hydraulic structures in concrete, while considering the requirements of the user and the different techniques used.

1 GENERAL - REQUIREMENTS OF THE USER

The technical requirements and specifications of the user in charge of the operation of a hydraulic facility in concrete have to do essentially with the following points: waterproofing of structures, properties and strength of any facings used, ease of execution (application), maintenance and repairs, compatibility of materials with the water or liquids, supply conditions, durability, longevity.

- **Waterproofing (References No. 1 and No.2)** Tanks, basins and water towers are classified according to the nature of their waterproofing as follows:

Class A - Facilities in which waterproofing is provided by the structure alone.

Class B - Facilities in which waterproofing is provided by the structure completed by a waterproof facing.

Class C - Facilities in which waterproofing is provided by a waterproof facing which is adherent or independent of the substrate, the structure providing only a mechanical function, while the facing provides waterproofing.

- **Properties and strength of facings** Depending on the function assigned to the membrane, different mechanical properties may be required, in particular when the facings are adherent or independent of the substrate.

- **Ease of execution, application, maintenance and repair.** Products and materials designed to provide waterproofing of a hydraulic facility must be easy to use and well-suited to the specific requirements of the facility involved.

It should be possible to complete repairs within the time interval called for by operating conditions.

- **Durability, longevity.** It is essential that products and materials used within a facility to provide waterproofing should be able to perform their function reliably for a period in excess of 10 years.

2 PREFABRICATED WATERPROOF FACINGS BASED UPON HIGH POLYMER MEMBRANES WHICH ARE ADHERENT OR INDEPENDENT OF THE SUBSTRATE

2.1 Thế products used (reference No. 1 - Chapter 6)

For construction, two major families of membranes are used: membranes not adhering to the concrete structure, in the form of sheets obtained by calendering, extrusion or coating ; membranes which are glued, adherent or bonded to the concrete structure and are generally in the form of sheets or slabs manufactured by continuous extrusion, possibly with grips formed in the final phase.

These membranes may be homogeneous, reinforced or combined. They are assembled in the factory or in the field by welding (hot air or heated wedge, possibly with filler material or solvent) by gluing or by vulcanizing, so as to obtain a sealed envelope. They may also be applied against the formwork of the structure before the placement of reinforcing steel and concreting.

These sheets or slabs are applied, after preparation of the substrate (or formwork), in a single layer. They may be placed in relation to the substrate in various ways: independent, fixed mechanically in the vertical or inclined parts (of the wall or formwork) or adherent (gluing in strips or over entire surface).

Non-adherent sheets are some times associated with a geotextile (nonwoven, anti-puncture) in order to improve their tearing strength and their dimensional stability.
High polymer membranes are distinguished by the type of resin and additives, possible textile reinforcement, thickness, width, mechanical properties. They generally do not require any surface protection (except in zones of water turbulence, transport or erosion).

2.2 General characteristics of products
The choice of the type of high polymer used and the formulation of the waterproofing membrane will be dictated by the nature, concentration, temperature and storage time, of the water, liquid effluent and tide levels.
High polymer based membranes are characterized by : their chemical properties, determining their application possibilities for the storage of various effluents of the chemical, petrochemical and agro-food industries (resistance to acids, bases, hydrocarbons, alcohols, oils, solvents, etc., to micro-organisms, but also inertia with regard to water, and supply possibilities); their mechanical properties (tensile strength, ultimate elongation, static and dynamic puncturing resistance, bursting strength..... ; their physical properties (low-temperature performance and dimensional stability).

2.3 Advantages and limits on use (references No. 1 in Chapter 7 and No. 2 in Appendix G)
2.3.1 Membranes which are glued, adherent or bonded to the structure
. Glued membranes: on a concrete substrate, they entail gluing problems.

The use of this technique requires control over a certain number of parameters such as:
- indispensable cleaning of substrate;
- possible treatment of substrate;
- choice of gluing product and contact and pressure application method;
- execution constraints related to a substrate which is generally wet, making the application difficult;
- temperature and humidity of surroundings or in the vicinity of the wall of the structure, which must be within strict limits during application.

This technique has certain drawbacks and in particular: risk of crack propagation through the coating (because of a crack or crackable substrate), blistering due to the evaporation of humidity (buried or semi-buried facilities), difficulty controlling leaks and hence of ensuring the effectiveness of the treatment.
. Anchored membranes: patterns or grips (spaced a few decimetres) forming an integral part of the membrane are anchored in the concrete when it is poured.
The use of this technique requires:
- a new structure to be built with flat surfaces or simple curvature;
- placing of the membrane against the formwork and nailing of slabs at precise points (near extruded sections serving as angular connection pieces, or between slabs) ;
- securing of concrete reinforcements in position, compliance with concrete covering thicknesses by means of devices offering little risk of tearing or grooving in the membrane;
- assurance that the formwork is not crossed by spacers and tie-rods, necessary for guaranteeing both the thickness of the structure and the stability (concrete thrust) of the formwork during the pouring and vibration of the concrete.

This technique has certain drawbacks, and in particular can be applied only to new structures and is little, or not suited to crackable walls beyond certain permissible values related to the relative deformations (ratio between the distance of the grips and the crack movement amplitude).
One advantage of this technique is that it can be used for structures designed to receive polluting products or to contain particularly aggressive effluents.

2.3.2 Membranes not adhering to the structure
The flexibility of these coatings, the independent application, the treatment of expansion joints, corners, connections on cross-pieces, with continuity, make them suitable for cracked or crackable substrates.
These coatings are particularly well-suited to repair works.
Careful preparation of the substrate (flatness, roughness, cohesion, cleanliness, etc.) is not necessary in the case of an independent application. However, depending on the condition of the substrate, it may be necessary to insert a protective felt (geotextile) between the concrete and the waterproof membrane.
The humidity of the substrate does not represent a utilization limit.
Constructional arrangements will take into account the dimensional stability of the different membranes; the manufacturer's specifications define the most appropriate application technique, according to the nature of the material and the characteristics of the structure.
This technique offers in particular the following advantages:
- preparation of substrate reduced to simple cleaning (mud, organic matter, removal of stones or various debris); the substrate does not have to be dry;
- relative insensitivity to temperature and humidity conditions;
- relatively fast execution;
- possibility of drainage: removal of infiltrations and checking of effectiveness of waterproofing;
- independent placement making the material insensitive to crack movements.

This technique has certain drawbacks; in particular, the methods used to fasten the geomembranes to walls and floor, cleaning and maintenance must be adapted ; very skilled peoples are needed to execute weldings and details, specially for the corners and connection to pipes, ladders, ...etc.

2.4 Design and application conditions

Possible use of a textile reinforcement and the application method depend on the inherent constraints of the structure (height, cracking, etc.) and its operating conditions (water flow conditions, cleaning and accessibility involving risks of static or dynamic puncturing, etc.).

Each process, adherent or independent, must indicate:

- bonding method (hot or cold), welding, gluing or mechanical attachment);
- width of covering strips (longitudinal and transverse) ;
- number and types of attachments (if necessary);
- details of particular points (piping, anchors, crossing and overlapping).

2.4.1 Design for independent systems

Prior preparation of the substrate is generally desirable as well as the placement of a geotextile and a drain at the base of the shell.

It is also desirable to provide attachments on the shells (vertical, inclined and re-entrant angles). On the floor, the membrane is simply placed and attached on the periphery without any intermediate attachment (except in current or turbulence zones, and at the corners of the bases of columns or sumps).

If the coatings are subject to shrinkage, an expansion loop at the wall-floor junction is preferable. The attachments are generally provided by PVC colaminated sheets attached by screwing or nailing on the concrete and on which the PVC membrane is welded.

The junctions of the geomembrane strips are heat welded. The assembly must be carefully overlapped and checked in place by a mechanical inspection (dry point) or by means of a vacuum bell or other approved means. Along the runs, the use of automatic machines is recommended. Detail finishing is carried out with manual hot-air devices.

2.4.2 Design for adherent systems

In principle, there are no mechanical attachments. Certain membranes, for example with a nonwoven polyester underlining, may be glued to the substrate, but the upper attachment remains obligatory. The junction and assembly methods, as well as the inspections, are the same as for independent systems. The gluing products are subject to testing and inspection.

2.4.3 Treatment of special points

For special points (expansion joints, angles, etc.), homogeneous membranes are used, in most cases in the form of thermoforms or mouldings. These membranes must support the differential movements that may appear at construction or expansion joints.

The technical approaches generally used are:

. Traversing piping, anchoring: they are equipped with a counter-flange, flange or collar, in homogeneous material, allowing the stopping of the waterproofing by clamping the membrane;

. Inert joints: bridging of joints;

. Expansion joints: provision of an expansion loop with a plastoelastic homogeneous membrane.

3 EXAMPLES OF APPLICATIONS- (Reference n°.3)

. The Ponte Corvo Canal project in Italy (Photo 1) demonstrates the use of a waterproofing PVC membrane protected by shotcrete 7-cm thick applied over a geotextile.

. The Marne Bergamo Canal in Italy (Photo 2) illustrates the application of a PVC membrane anchored longitudinally on top on the slopes, not protected on the inclined walls and ballasted on the ceiling by a concrete layer providing mechanical stability, protection against flow transport, and allowing cleaning and maintenance operations.

. View of relining site for a masonry tank in Toulouse, France (Photo 3). Attachment of membrane on sheets anchored in the masonry at angular points and in the vault, at distances allowing the curvature to be followed substantially.

. Application of a membrane lining in the cylindrical drinking water tank of Meylan in France (Photo 4). The floor, the walls, many columns are lined with a membrane anchored at the top, at the floor-wall junction and at the base of columns.

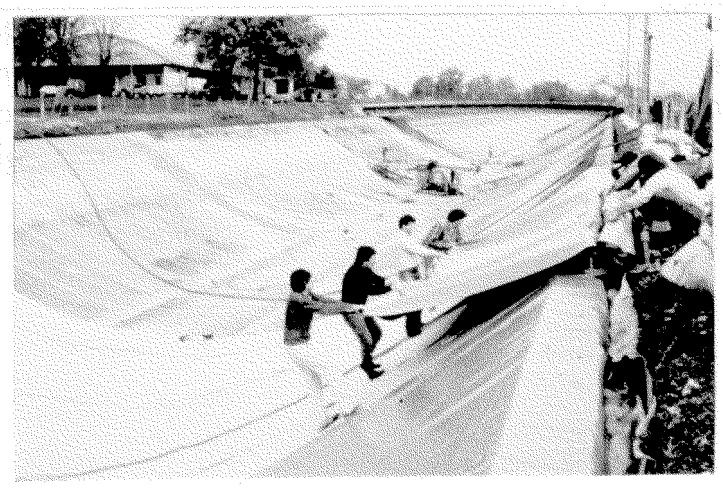
. Protection of a canal and of a concrete structure in Forez, France (Photo 5). The protection of the banks, and the connection of the canal with the siphon head, shows various applications of bituminous membranes, while highlighting the importance of the treatment of singular points.

4 REMARKS AND CONCLUSIONS

The variety of products used, the methods employed (independent or adhering on substrate), and the applications to new or rehabilitated structures, demonstrate the diversity of the technical approaches possible on the growing number of jobsites. The photographs show various structures in masonry, concrete or reinforced concrete, new or old, corresponding altogether to the field of application of membranes.

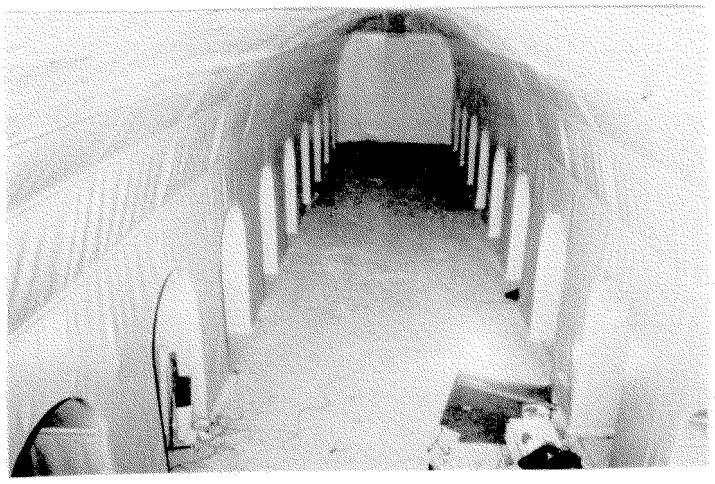
BIBLIOGRAPHY

1. Recommandations professionnelles mai 1990 - Annales I.T.B.T.P. N° 486 septembre 1990.
2. Revision of Section 74 of CCTG (specification).
3. Rencontres 93 geotextiles-geomembranes - Joué - les-Tours - (France)



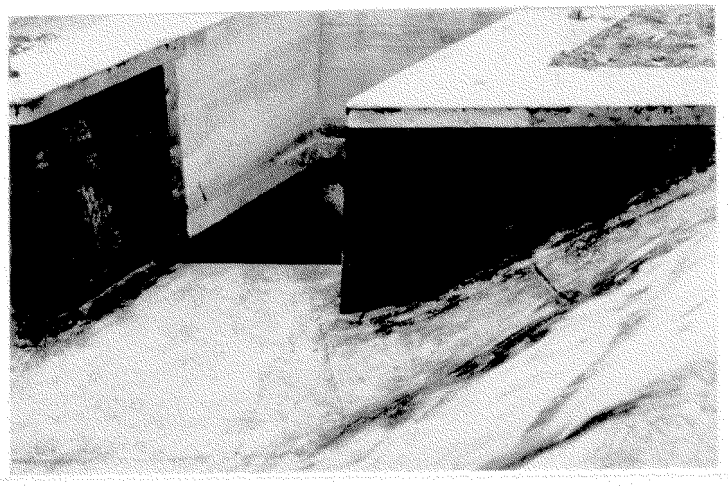
Photograph 1 - View of Ponte Corvo site in Italy

Photograph 2 - (ITALIE)/*Marne Bergamo canal in Italy*



Photograph 3 - View of a masonry tank relining site in Toulouse (FRANCE)

Photograph 4 - Water tank in Meylan (FRANCE)



Photograph 5 - *Protection of a concrete. Singulars points -/Connection of a canal and siphon head -/Forez (FRANCE)*