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WATERPROOFING SOLUTION OF AN EXISTING BASEMENT AGAINST WATER UNDER HYDROSTATIC PRESSURE. CASE STUDY

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Abstract: *Incorrectly performing field investigations can lead to the design of waterproofing solutions to the infrastructure of a building, in complete disagreement with the specific situation, difficult to achieve or even impracticable. In this context is included the present paper, which contains a case study on a building in progress, for which the waterproofing solution of the basement was designed in the classic version, with bituminous membranes and the presence of underground water under pressure has made the proposed solution impracticable, and procedures for lowering the level of the groundwater very costly. The solution presented in the paper allowed waterproofing of the basement in the presence of moisture.*

Key words: *concrete, waterproofing, Penetron, durability, chemical reactions, layer.*

1. Introduction

1.1. General Causes of Concrete Degradation

Concrete is the second most consumed product on earth after water. Durability of hydraulic cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment [2].

The main reasons for concrete deterioration are according to Figure 1.

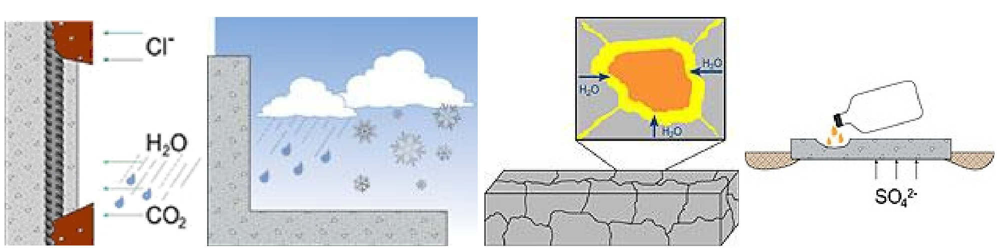

Fig. 1. *Concrete deterioration reasons*

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From the picture above (Figure 1) we can identify, from left to right: corrosion of reinforcement steel, freezing and thawing, chemical reactions of the aggregate (alkali-silica reaction/alkali-aggregate reaction) and chemical attack [4].

Through cracks, voids and pores, concrete allows water to penetrate and deliver corrosive chemicals that eventually attack the steel designed to strengthen it. Once corrosion starts, it is difficult to determine the extent of the damage as it can occur anywhere along the network of steel reinforcement [4].

Furthermore, under freezing conditions, water trapped inside concrete turns to ice and expands, creating cracks.

Concrete durability can be achieved in several ways: traditionally or by using different materials such as Penetron admix. The first one implies more cement/low w/c ratio, high compressive strength, air entraining admixtures and corrosion inhibitors. As related to Penetron admix this means low permeability, low shrinkage, self-healing and protection against chemical attack.

1.2. Main Waterproofing Solutions

Underground waterproofing may be:

- Against the moisture from the earth;
- Against waters without hydrostatic pressure resulting from infiltration in the ground of rain waters, snow melting and so on;
- Against water with hydrostatic pressure, that is to say, those who are found in the ground in the form of groundwater.

At the level of building basement the type of waterproofing (nature and number of component layers) is determined according to destination and exigencies imposed by the regulations.

Underground waterproofing against water with hydrostatic pressure is carried out on buildings with basements below the maximum level of groundwater.

Waterproofing against groundwater under pressure usually applies to the front of the building from which it is being exerted water pressure. Depending on the face of the building on which the waterproofing is applied, the following two cases are distinguished:

- waterproofing applied outside the building;
- waterproofing applied inside the building (inner tanking system).

Waterproofing against water with hydrostatic pressure consists of 3÷5 layers of bitumen sheets or fabrics depending on the hydrostatic pressure [1].

There are also requirements according to standards specifications and mainly we aim to waterproof by creating a mechanical barrier or by making the waterproofing mass.

2. Practical Solution for Waterproof Insulation of Existing Basement in the Presence of Moisture. Case Study

2.1. General Considerations on the Existing Situation

The building presented in the case study is located in Brasov County, on a plan site, in a groundwater discharge area collected from the mountain massif and the adjacent plateau. The building is intended for single-family dwelling and a height regime Sp+P+E, according to Figure 2. Some more constructive details are presented in Figure 3.

Fig. 2. *Overall building view*

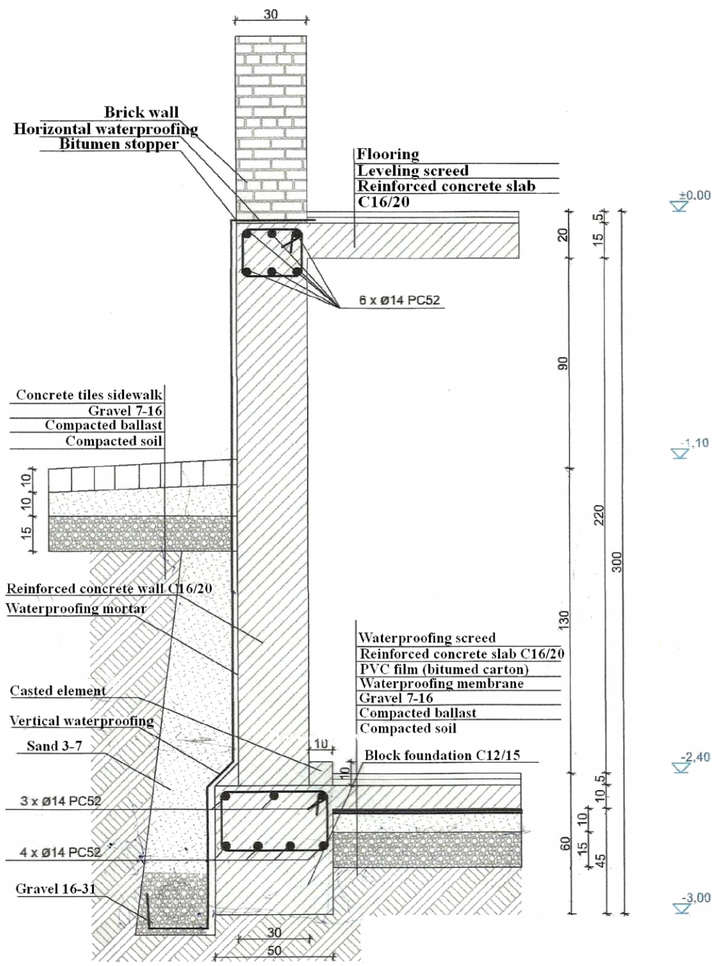

Fig. 3. *Initial waterproofing designed solution of the basement*

The building was designed in the following constructive solution:

- Rigid continuous foundations of simple concrete block and reinforced concrete element in the basement area;
- Rigid continuous foundations of a simple concrete block and a reinforced concrete base under the walls of confined masonry;
- Reinforced concrete walls in the basement area and confined masonry for the superstructure;
- Reinforced concrete slabs;
- Reinforced concrete staircase with straight ramps and intermediate platform;
- Wood roofing and profiled tile roofing.

The underground waterproofing was designed against wall moisture applied externally to the walls in the form of cold applied bituminous mastic for walls and two bituminous thermosetting membranes applied on the concrete support layer underneath the reinforced concrete slab of the basement floor (Figure 3).

In the technological phase of preparing the capillary rupture layer beneath the support slab of the horizontal waterproofing, performed during a rainy period of the year, the high level of the groundwater was found, at about 1.0m compared to the natural ground quota, much higher than the one indicated in the geotechnical study, lower than 5.0 m from the ground.

The presence of groundwater above the horizontal waterproofing layer made the project designed solution impracticable, and the lowering of the groundwater level led to unacceptable costs for the owner.

In the given situation a waterproofing solution of the basement was adopted, which allows application under the existing field conditions.

2.2. Principle of the New Designed Solution

The principle of the adopted solution was the realization of a reinforced concrete interior tank, by using in the composition of the concrete a Penetron admix waterproofing additive, in the proportion of (0.8-1.0)% related to the cement quantity, and the infiltration areas in the existing basements were treated by injection and refilling cracks (after opening) and voids in the concrete mass with Penecrete mortar, Penebar SW-45 and Peneplug.

The waterproofing effect obtained with Penetron products is based on the multiplication mechanism of crystals formed in the presence of water, which penetrate and fill the pores of the concrete mass.

When Penetron Admix is added to the concrete, the crystalline components react with water, calcium hydroxide and aluminium as well as various other metal oxides and salts contained in the concrete.

The chemical reaction that follows causes these voids and cracks to be filled with insoluble crystals. Therefore, water is unable to pass through these crystal formations, and as a result the concrete becomes impermeable [4].

If we take for example a stearate admixture, the chemical reaction that occurs is: calcium hydroxide (lime) + stearate admixture → insoluble calcium stearate + water (1) [3].

$$Ca(OH)_2 + RCOOH \rightarrow Ca^{+}COOR^{-} + H_2O. \quad (1)$$

2.3. Materials Used on the New Waterproofing Technology

For the case study, the following materials were used, according to specific technology: Penetron admix, Penecrete mortar, Penebar sw-45 and Peneplug.

- **Penetron admix (PA)**

It is a mixture of active ingredients in powder form that is added to the concrete to form an insoluble crystalline structure. The crystals form deep inside the concrete, sealing the pores, capillaries and shrinkage cracks from water penetration. Therefore, this product provides comprehensive protection against concrete deterioration caused by chemical attack, freeze-thaw cycles and corrosion, while withstanding high hydrostatic pressure. Its dosage rate is 0.8-1.0% by weight of cement and added during batching, it can significantly increase concrete durability and service life.

Tests and requirements to obtain high performance durable concrete are presented in Table 1 [4].

Test and requirements of PA Table 1

Type of test	Property	Standard	Requirement
Exposure to freeze-thaw cycles	Freeze-thaw resistance	BS 5075-2 or NCh 2185	≤ 0.05% change in length by expansion
Exposure to sulfate attack	Expansion due to sulphate exposure	ASTM C1012-13 and ASTM C1157	≤ 0.05% change in length by expansion at 6 months and <0.10% at 12 months
Exposure to chloride attack	Chloride diffusion	ASTM c1556-04	Years of service life of the structure before start of corrosion of steel reinforcement.
Mechanical resistance	Compressive strength	NCh 1017 and NCH 1037	> 30 MPa
Llength changes due to drying	Drying shrinkage	NCh 2221	< 0,8 mm/m per 1 year.
Permeability	Water penetration resistance	DIN 1048	≤ 20 mm average penetration
Capillary absorption	Water absorption	ASTM C 1585, Manual DURAR CYTED	Coating 3 cm, ≤ 5E-05 $m/s^{1/2}$ (severe environment)

- **Penecrete mortar**

This product consists of Portland cement, specially treated quartz sand and a compound of active chemicals.

The active chemicals react with moisture and the by-products of cement hydration to cause a catalytic reaction, which generates an insoluble integral crystalline complex. These crystalline complexes grow in the presence of water and block the capillaries of the concrete and minor shrinkage cracks, thus waterproofing the concrete. Chemical activation begins when the powder is mixed with water and may take several days to completely block the capillaries, depending on ambient temperature and environmental conditions [4].

Depending on surface conditions, we present some approximate values of consumption and yield of 22.7 kg bag.

- U-shaped cracks and reglets: 25 mm x 25 mm size; 4.9 kg/m^2 consumption, ~ 15.2 m yield/bag;
- Coves, triangular shaped: 38 mm x 38 mm size; 4.9 kg/m^2 consumption, ~ 15.2 m yield/bag;
- Tie holes: 25 mm x 25 mm x 25 mm size; ~ 600 nos yield/bag;
- Honeycomb and surface patching: ~ 0.01 m^3 / bag.

• **Peneplug**

Peneplug is a rapid setting, integral crystalline cementitious waterstop designed to stop active water leaks and moisture ingress and is available in 18 kg or 25 kg bags.

It can be applied on concrete, masonry, earthenware or stone. The substrate must be clean, sound and free of any surface contamination, such as oils, coatings, paints, dirt and so on. Leaking areas must be cut back to sound material, leaving an appropriate chase for receiving the treatment.

• **Penebar SW-45**

Penebar SW is an expanding strip waterstop that expands to form a positive seal against the concrete when in contact with water. It provides an optimal upgrade over passive PVC and rubber dumbbell waterstops by eliminating the need for special parts, tie-ins, split-forming and seam welding. The effect in concrete is presented in Figure 4 [4].

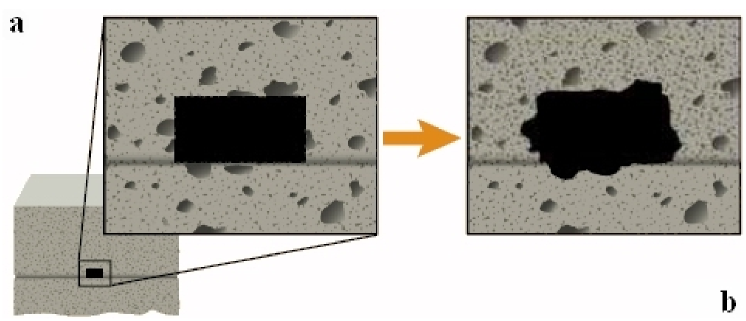

Fig. 4. *Effect of Penebar SW in concrete, before (a) and after hydration (b)*

The Penebar product with the code sw-45 rapid can be used in building foundations, slabs, retaining walls, storage tanks and other similar non-moving cold construction joints.

It is packed in 30 meters/carton (6 rolls, 19 mm x 25 mm x 5 m each) or 24 meters/carton (6 rolls, 9 mm x 25 mm x 4 m each). It can, also, be applied by using brush at a minimum of 0.1mm thick by 25 mm wide over the entire surface length.

The expansion rate when immersed in fresh water (a) and salt water (b) can be observed in Figure 5.

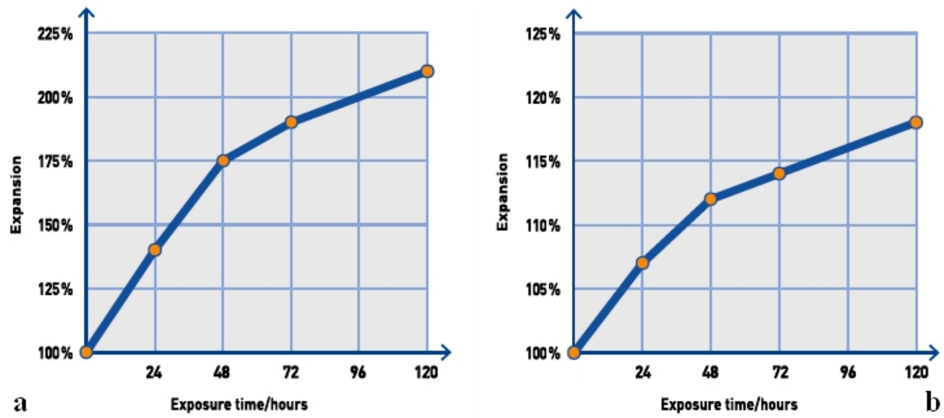

Fig. 5. *Expansion rate when immersed in fresh (a) and salt (b) water*

2.4. The Technological Phases of Work

For the complete draining of the building basement, the following technological phases were completed:

- Execution of the support slab of the low-reinforced concrete basement, in which Penetron admix was introduced, and in the contact areas with the existing walls an expandable strip was arranged;
- Injecting and filling the open cracks or existing holes with Penecrete mortar, Penebar, Peneplug, according to Figure 6.

Fig. 6. *Waterproofing by injecting Penetron products*

- Doubling the basement walls on a height of 1.0 m with reinforced concrete and addition of Penetron admix according to Figure 7:

Fig. 7. *Execution of inner tank walls*

- Local interventions by injection with Penetron admix, refill with Penecrete mortar and / or Peneplug.

Following the listed operations, the basement of the building was fully secured against pressurized water.

3. Conclusions

The waterproofing solution of the existing basement, presented in the paper, is distinguished by the following features:

- It is applicable in the presence of pressure waters;
- Requires low costs to maintain an acceptable groundwater level;
- Application costs are comparable with those of the original designed solution.

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