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Structural Problems Occurring in Reinforced Concrete Drinking Water Tanks and Water Loss Prevention Methods

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ABSTRACT- Water losses occur over time due to structural deformation in buried reinforced concrete tanks built to meet the drinking water needs in living spaces. It is clear that drinking water tanks must be strengthened and waterproofed to prevent tons of water loss every year. A water-repellent coating on the concrete surface of water tanks prevents water loss as well as effectively protecting the concrete and increasing its durability. Waterproofing not only provides protection, but also prolong one's life of the building. The key to success in waterproofing all engineering structures is the proper and appropriate application of the right waterproofing materials.

The aim of this study is to prevent water losses due to structural problems that occur over time in four recessed rectangular prismatic reinforced concrete clean water tanks in four different locations in a province in Turkey, to extend the life of the facility and most importantly to provide cleaner potable water to human life. Water and Sewerage Administration started maintenance, repair and waterproofing works of 15,000 m3 water tanks in the city center in 2021-2022. This article, academic articles, previous practices have been researched and it is hoped to be a solution to the problems. Considering the causes of water loss in the existing water reservoir, it is hoped that it will be a guide for the construction of a new water reservoir.

KEYWORDS- Waterproofing, Waterproofing Methods and Materials, Synthetic Cover, CCCW, Polyurea, RC Water Reservoirs Structures, Water Tank, Water Losses

I. INTRODUCTİON

A. Embedded Rectangular Prismatic Reinforced Concrete

The clean water tank is a symmetrical structure with two common compartments on one of its long walls and a wave-breaking curtain wall in each compartment. (see Figure 1) Clean water is transferred to the city water network via main pipelines from the room in front of the water tank. Ground settlement, which will cause cracking of the tank floor, is compensated with the help of dilatation joints placed on the tank floor to reduce shrinkage and temperature effects.

In addition, in order to protect the drinking water inside the water tank against overcooling and overheating, there is up to 1 meter of soil above the ceiling in the embedded tanks [1].

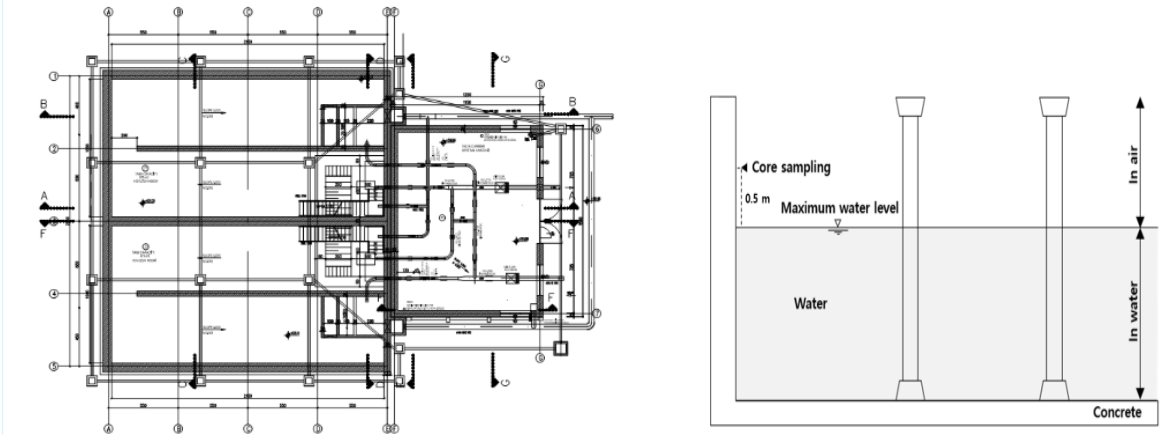


Figure 1: Embedded Water Tank Two Cells Prismatic Reinforced Concrete Type Project

The desire to remove water from buildings existed not only today, but also during the time of the Romans and Egyptians. The ancient Romans thought to divert water away from buildings constructing foundation walls huge thick that the water could not penetrate. It is clear that the ancient Egyptians used asphalt to remove water from the foundations of the pyramids. They applied bituminous material to the interior and exterior of some buildings in order to dewater the ground, and they also used it in the construction of cisterns [2].

B. Damage Caused By Water Leakage

When building elements are exposed to water and moisture for a long time, they will not provide the comfort expected from them. Water and moisture trigger the corrosion of steel reinforcement and rust is the most important factor causing deterioration of structural elements[3]. Corrosion influences durability of reinforced concrete buildings and manifests itself at an advanced stage in the form of bursting and flaking of the concrete pavement.[4].

C. Damage caused by chloride

The chlorine ion in the concrete remains in the concrete as a natural consequence of this evaporation of water, as the number of repetitions increases, the chloride ion density increases. In addition, chloride ions from chlorine disinfectants used to purify drinking water penetrate into the concrete in the water tank. At the end of this stage, it can be assumed that corrosion begins in the reinforcement, cracking and other physical damages begin to appear in the structural element, and the amount of these damages increases over time. This makes the latter the most dominant cause of damage to the water tank. Waterproofing (WP) of concrete preserves its structure, preserves its quality and extends its service life[5]. In concrete structures in general, WP systems provide an external impermeable barrier for the transport of water and the blocking of pores. The WP system increases the resistance to wetting or restriction of water flow due to the porous structure of the concrete.

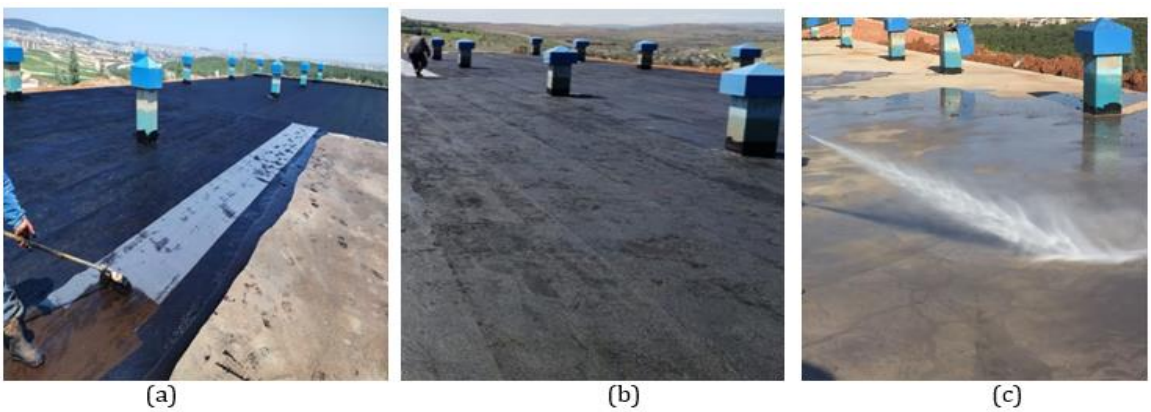
II. REİNFORCED CONCRETE RESERVOİR WATERPROOFİNG METHODS

Reinforced Concrete Reservoir Roof Waterproofing; Prismatic reinforced concrete water reservoirs are made as recessed according to their location on the ground. This type of water reservoir is covered with soil up to 1 meter above the reservoir to prevent the drinking water in the tank from being affected by the external environment. For this reason, it is the soil at a height of 1.00 m that keeps the rain, hail or snow water on the roof of the reservoir as shown Figure 2. It usually causes further infiltration downwards. Water infiltration into the concrete continues to progress over time from the base slab to the shear concrete and foundation. Also due to the lack of proper settling and the fact that the air temperature is different, water can seep into the structural elements through pores or slight cracks, no matter how small they may be. Therefore, waterproofing to prevent water infiltration becomes indispensable for the life and durability of the structure. In water tanks where maintenance and repair is carried out, it is necessary to remove the soil cover on the tank as a priority. Then the surface must be cleaned for application.

(a) (b) (c)

Figure 2: (a) Water Tank Roof (b) Removing Soil From Roof (c) Cleaning The Roof

After cleaning, bitumen-rubber based (two-component) waterproofing material[6] was chosen as the waterproofing material in order to completely cover all the pores on the concrete surface (see Figure 3) In this application, a synthetic cover was applied in two layers to serve as a skeleton.



(a) (b) (c)

Figure 3: (a) First Layer Waterproofing On The Roof Surface, (b) Second Layer Waterproofing On The Roof Surface, (c) Waterproofing Screed

A drainage line was laid around the tank to drain the snow, hail and rain water while waterproofing the tank. .

(a) (b) (c)

Figure 4: (a) Roof Water Drainage Flooring, (b) Roof Water Drainage Filling, (c) Water Tank Roof Filling Work

Afterwards, an inclined screed was made to protect the insulation on the water tank sump. Approximately 5 cm of gravel aggregate was filled on the screed (see Figure 4).

A. Repair and Waterproofing Of The Joints

Cement based adhesion and corrosion control mortars containing high quality cements, silica fillers, silica fume additives and performance enhancing chemicals were used to repair tired holes in reinforced concrete walls and deformed exposed concrete surfaces in the tank. (see Figure 05)

(a) (b)

Figure 5: (a) Leakage Between The Pores of The Water Tank, (b) The Surface of The Concrete İn The Water Tank

In the connection of two reinforced concrete walls and the connection of a reinforced concrete wall and a foundation, there is more reinforcement in terms of strength. For this reason, the concrete may not settle completely and create a gap and this may cause water loss. In order to minimize water loss, corner chamfers were made as 10x10 cm with cement-based fiber and polymer reinforced, high stability gross concrete repair mortar at the corner joints. (see Figure 6) Then, a polypropylene-based, polyurethane film-reinforced, waterproof, elastic 12cm joint tape will be glued on it.

(a) (b) (c)

Figure 6: (a) Wall and Base Junction of The Water Tank, (b) Horizontal Chamfer Application, (c) Vertical Chamfer Application

B. Waterproofing Of Dilatation Joints

The fact that the water tank has been subjected to ground settlements over time, the pressure of the water in the tank and the earthquake loads have caused deformations and separations between the dilatation joints over time.

Figure 7: (a) Initial Condition Dilatation Joint, (b) Cleaning The Dilatation Joint With Blowtorch, (c) Cleaning The Dilatation Joint With Air Compressor

Therefore, it was foreseen that the dilatation joints should be renewed. Stage 1 is to dismantle the existing dilatation joint and clean the joint gap (see Figure 7). In the dilatation joint cleaning process, after the old insulation material is removed, the joint cavity is cleaned with air, then the old insulation is burned with a blowtorch to destroy small pieces of insulation. Then, after applying adreance to the cleaned surface, a wick of suitable diameter was placed. Then the dilatation joint was filled with elastic mastic. In order to protect the dilatation joint, flexible bands should be glued with epoxy on the dilatation joint to avoid being affected by the internal pressure in the water tank and the movement of the earthquake load (see Figure 8).

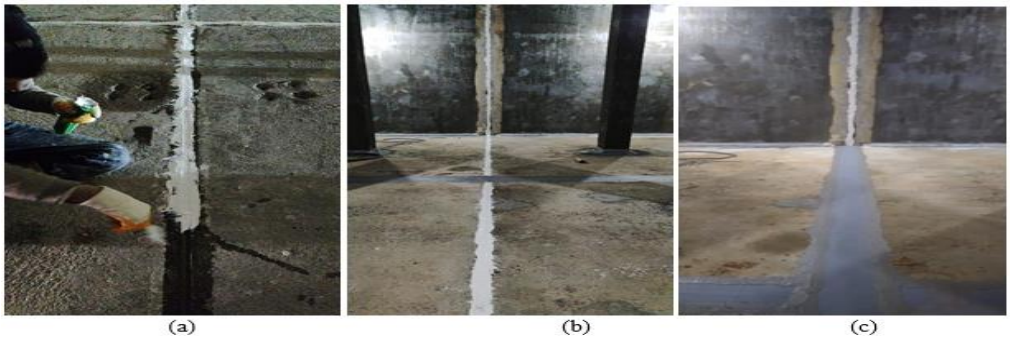


Figure 8: (a), (b), (c) Vertical And Horizontal Expansion Joint Waterproofing Stage Application

C. Waterproofing Made On The Curtain Wall And Pavement Inside The Water Tank

Waterproofing was chosen with a cement-based mixture of crystallizing agents that penetrate into the capillary channels with moisture to create a waterproofing effect and penetrate deep to fill the capillaries and react with moisture and components in the substrate to form crystals (see Figure 9) and thus create a waterproofing effect to close the moisture, non-pressurized and pressurized water on the surface on both the positive and negative sides. [7].

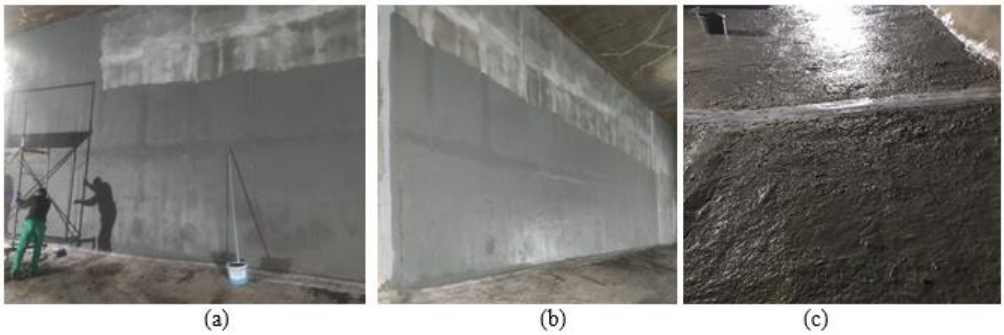


Figure 9: (a) (b) (c) Application Of Cement Based Crystallized Waterproofing Stage

III. MATERIALS

In the Regulation on Waterproofing in Buildings in the legislation in Turkey, Section Eight, Waterproofing in Water Tanks and Pools, Article 26 (3) 'In water tanks, it is essential that waterproofing materials in contact with drinking and utility water are made of materials that will not interact with water and will not deteriorate the quality of water. Insulation materials cannot contain solvents and cannot be bitumen based[8].

There are many different methods in practice to prevent or seal water losses in the reinforced concrete water tank and to

eliminate the possibility of corrosion. In this context, waterproofing materials such as synthetic cover (PVC, EPMD, etc.), polyurea and cement-based crystallized materials were investigated on the curtain walls and floors of reinforced concrete water tanks.

A. Water-Based Permeable Crystalline Waterproof Material

Cement-based capillary crystal waterproofing materials (CCCW) penetrate into the pores in the concrete, fill the voids and strengthen the concrete by minimizing porosity.The active chemicals contained in CCCW materials can penetrate into the concrete with water and penetrate into the capillary gaps in the concrete. During this process, the active chemicals in CCCW will multiply calcium ions and challenge the formation of calcium silicate and calcium carbonate in the pores[9].As a conclude, excellent protection of CCCW can be expected by filling the cavities with calcium ions [10-11]. Liu and others. [12]
Increasing the tightness of the concrete will be lamented by minimizing the voids.As a result, this event will cause us to increase the strength of concrete[13].

B. Waterproofing with Synthetic Cover (PVC, EPDM, TPO, ECB/ECO, etc.)

Synthetic Cover membranes are a waterproofing material commonly used to keep structures away from water. These types of membranes can be deformed due to climate and weather conditions and are vulnerable to impacts.
It is essential to repair the damages that will occur in synthetic cover materials due to these factors in a localized manner.This type of damage on the synthetic cover requires re-covering the damaged parts with synthetic cover again, between the old and new synthetic cover [14].

C. Spray Polyurea Elastomer

Spray polyurea elastomer is a building material that has started to be preferred today. Since it is not affected by external factors and strengthens the structure, it has become a focal point in waterproofing engineering. The spray polyurea structure is placed with a special main machine and spray gun to isolate the inside of the water tank.
The polyurea used as a waterproofing product should be applied with the help of a motor and the raw material should be applied to the application area with a spray gun in an equal thickness. The coating formed when the polyurea is sprayed on the base layer gels and the coating hardens completely after 5~10 seconds [15] Therefore, it is important for the health of the waterproofing application and workmanship should be sensitive.

IV. DISCUSSION

Synthetic Cover (PVC, EPDM, TPO, ECB/ECO, etc.) rehabilitation of waterproofing materials includes a) dismantling of waterproofing systems and replacement of damaged layers, b) Re-applying waterproofing over the damaged area, i.e application of joints between the damaged membrane and new membranes. There are two basic methods for the second approach.
It should be ensured that repair techniques and necessary materials are used to repair the damaged synthetic cover.Unsuccessful repair on a waterproofing membrane indicates how poorly the joints between the waterproofing membranes are adhered. [14].
In order to make synthetic cover in the water tanks in question, the ground must be flat. This will create an extra cost. As a result of the tests carried out, it was evaluated that the joints of the PVC synthetic cover were separated over time. In addition, pvc synthetic covers used as waterproofing in the structure will not benefit the durability of the structure since it is not a surface strengthening material.
Spray Polyurea Elastomer; However, the results obtained on the leakage prevention of polyurea coating are based on only a few simple tests and rough qualitative assessments. There is still a lack of systematically measured test data and comprehensive quantitative analyses in experimental research. Spray Polyurea Elastomer was not preferred by Water and Sewerage Administration for the reasons mentioned, as it is an expensive material and is expected to be difficult to repair when repairs are required.
In addition, since synthetic cover and polyurea applications are different materials from concrete, they will work differently with concrete. The internal pressure in the water tank will cause separation when it cannot be whole with concrete due to different loads. Considering these situations, it is not deemed appropriate to be used as waterproofing.
Spray polyurea elastomer and cement based permeable crystalline waterproofing materials are surface reinforcing materials. These materials used in waterproofing applications also increase the durability of the RC structure.According to the researches, it has been proven by experiments that CCW is more durable[16] .
CCCW provides both strength and waterproofing to concrete by filling capillary gaps.Since it is cement-based, when the concrete combines with the surface, it moves together and there is no separation from the concrete surface.Cement-based capillary crystal waterproofing coating has advantages such as accessibility to the material, workmanship, repair according to the maintenance situation and cheap cost.
Due to the mentioned advantages, it has been found suitable to be used by Water and Sewerage Administrationas a waterproofing material in water tanks with a capacity of 15.000 cubic meters.

V. RESULT AND DISCUSSION

As a result of the research, Leak tightness tests were carried out on water tanks with a capacity of 15,000 cubic meters, the maintenance and repair of which were carried out by GASKİ. International standards (ACI, BSI) have been taken into account. The water tank was filled with water, ensuring that the water tank leaked 0.1 percent in any 24-hour period (see Figure 10).
The water tanks, whose waterproofing works were completed by Water and Sewerage Administration, met the standards in the tightness test.
On February 6, 2023, two earthquakes of magnitude 7.8 Mw and 7.5 Mw occurred nine hours apart, with epicenters in the Pazarcık and Elbistan districts of Kahramanmaraş.
In the earthquake of February 6, 2023, the subject of this article, four water tanks with a capacity of 15,000 m3 were not damaged and there was no loss of drinking water.The effectiveness of the waterproofing we applied was directly observed.

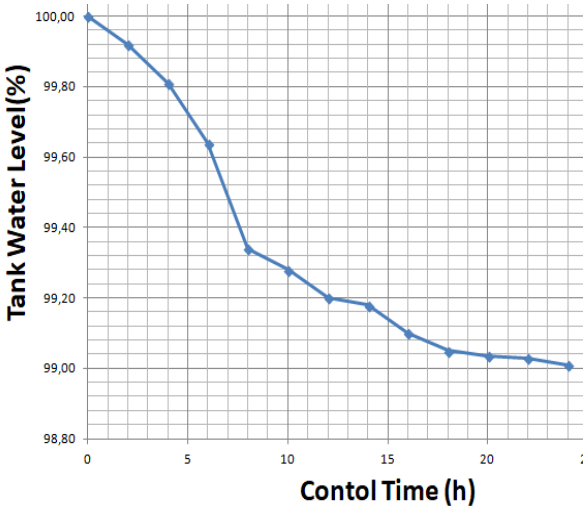


Figure 10: Contol Water Tank 24-hour period

VI. CONCLUSION

15.000 m3 capacity reinforced concrete water tanks are prepared as a type project by the public institutions. This project is implemented by the relevant institutions in Turkey. It is hoped that the implementation of this type of water reservoir by the relevant institutions will be taken into consideration and guiding in order to prevent the recurrence of the problems experienced.

At a time when it is said that the Third World War will be a water war, we should strive not to lose even a drop of water for our future.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest between them and with any third party.

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