Corrosion Problems in Buildings Constructed in Turkey

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ABSTRACT

Corrosion is the deterioration of metals due to chemical and electrochemical reactions. Corrosion is a costly problem occurring in metals and alloys and changes their physical, chemical and electrical properties. Economic loss due to corrosion in Turkiye is about 5% of its gross national income. Most metals are sensitive to water and air and undergo corrosion even under normal conditions. Corrosion occurs when oxygen, humidity and electrolytes are present in the medium. This study investigates corrosion and its reasons in concrete reinforcements.

Keywords: *Korozyon, Kimyasal reaksiyon, Yapı çeliği, Betonarme donatı.*

1. Corrosion and its reasons

1.1 Definition

Corrosion is the deterioration of metals due to chemical and electrochemical reactions [1]. In civil engineering terminology, corrosion is rusting of the reinforcement and causes decreases in its strength. In concrete building, reinforcements are especially prone to corrosion. Corrosion in reinforcements result in significant profile loss and bonding between building and reinforcement is lost. Therefore, reinforcement and building is no longer a unified structure and will start to behave on their own. Moreover, lead-bearing capacity of the building significantly decreases due to the loss of bonding between carrier elements of the building.

1.2 Types of corrosion

Corrosion can be classified as follows.

Uniform corrosion; It develops throughout the metal surface with a constant speed. That is how normal corrosion is expected to occur. The metal gets thinner homogenously due to this type of corrosion.

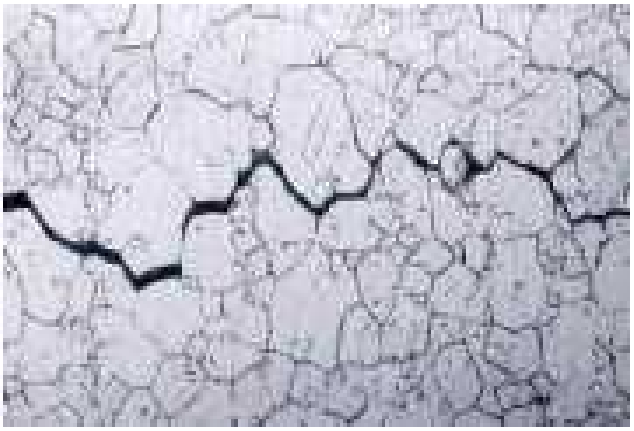
Pitting corrosion; It shows itself with occasional pitting on metal surfaces. Anode and cathode regions are definitely separated from each other. Anode is a narrow region on the surface of pitting whereas cathode is a wide region around pitting. Pitting gets bigger as corrosion proceeds and metal is punctured at the end of the process. Pitting corrosion is a very dangerous type of corrosion.

Crevice corrosion; Oxygen transfer is limited in regions such as crevices, gaps and pockets where the solution is stagnant. As a result, these regions become anode while metal surfaces around crevice become cathode. Crevice corrosion does not only occur in a crevice on a metal surface, it can also occur in between a material and a metal surface.

Filiform corrosion; It occurs due to corrosion of metal surfaces and will form as a film under the surface [2].

a

b



c **d**

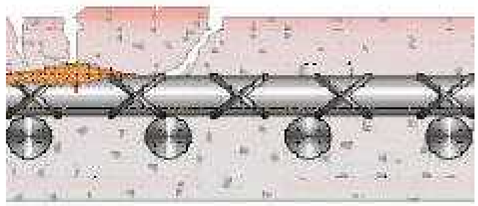
Figure-1.) a) Uniform Corrosion **b)** Pitting Corrosion **c)** Crevice Corrosion **d)** Filiform Corrosion

1.3 Why does corrosion occur?

Reinforcement corrosion in concrete building may start because of one of the two following reasons.

- Concrete cover in concrete elements undergoes carbonation and loses its alkalinity due to lack of concrete impermeability, resulting in deformation of protective cover and reinforcement may be subjected to corrosion.

- Corrosion in reinforcement may be due to effects of chloride ions. Concrete buildings in seashore areas are especially subjected to this kind of corrosion because chloride ions penetrate into concrete cover and negatively affect reinforcement [2].



(a)

(b)

(c) **(d)** **(e)**

Figure 2) a) Corrosion formation **b)** Reinforcement corrosion in BOTAŞ-Ceyhan Dörtyol facilities **c-d-e)** Corrosion damages in various buildings.

In both cases, the start of corrosion depends on the permeability of concrete cover. The extent of corrosion in reinforcement subjected to corrosion due to aforementioned reasons depends on the availability of oxygen and the possibility of moisture migration from concrete cover to reinforcement.

1.4 Losses due to corrosion

Studies have shown that monetary loss due to corrosion is about $ 4.4 trillion in the world and $ 46 billion in Turkiye. Economic loss due to steel corrosion is about 70 billion dollars in the United States. Corrosion is not only threat to economy, but it also is a threat to human health. Iron and steel is produced in about 14 million tons in the world and their corrosion is a serious threat to human health.

Turkiye had a massive earthquake on August 17, 1999 measuring 7.5 in Richter scale. Gölcük, Kocaeli was the epicenter of the earthquake. Based on official records, 17,480 people were dead, 23,781 injured, and 505 disabled. 285,211 homes and 42,902 businesses were damaged. Although not known in detail, lack of water insulation in buildings was the main reason of these collateral damages.

Water leaking into reinforcement for any reason freezes and accelerates chemical reactions damaging reinforcement and causing corrosion or oxidation (rusting). Formed corrosion weakens load-carrying system of the structure (building). In about ten years, the building loses about 66% of its original load carrying capacity owing to corrosion.

Although Turkey has made some progress in reconstructing damaged buildings and passed tougher regulations for earthquakes, the country does not seem to be totally ready for a possible Marmara earthquake. Damage Evaluation Commission of Istanbul Metropolitan Municipality has inspected 55, 651 homes and reported that 79% of these homes have major damage. 64% of home had corrosion (rusting) problems due to moisture, 41% did not have enough structural material to begin with, 18% was improperly watered (concrete) during construction, 11% were old and eroded, 3% had improper project plan. Therefore, Turkiye, in the epicenter of many earthquakes must take stringent measures for water proofing because concrete is the main material used in the construction of buildings. The report by Istanbul Metropolitan Municipality further stresses the importance of corrosion in buildings.

Figure-3.) Pictures from 1999 Golcuk earthquake

1.5 Factors affecting corrosion rate

Steel is subjected to corrosion almost under any condition as long as oxygen and water are present. The rate of corrosion depends on environmental conditions. Water rate, its alkalinity or acidity, fluctuations in temperature due to metal movement, presence of bacteria and other factors may increase corrosion rate. Corrosion also accelerates when the material is not pure. Using protective layers in a material, on the other hand, decelerates corrosion.

1.6 How can corrosion be prevented?

Several protective measures have been proposed to prevent corrosion. They are as follows.

1) **Use of pure metals:** Pure metals are used in many applications and use of pure metals minimizes homogeneity problems preventing pitting corrosion to a great extent.

2) **Alloy addition:** Corrosion resistance of many metals can be improved by adding alloy to metals.

3) **Heat treatment:** Segregation occurs in most casting pieces. Heat treatment such as homogenization, solvent addition and stabilization can make casting pieces more homogenous and improves their corrosion resistance [3].

4) **Optimum design:** Corrosion can be prevented by using an insulation material in the region where pin and bolt is in contact with metal sheets or by applying zinc chromate to contact surfaces and painting them with aluminum.

5) **Cathode protection:** Cathode protection requires polarization of corrosion affected metals. This can be achieved by pairing metal with an active metal or by applying external current.

6) **Use of corrosion inhibitors:** Due to earthquakes, ground floor of several concrete buildings has damages in concrete cover of reinforcement and concrete cover leaves the concrete as a result. This is attributed to throw cover, which is caused by an increase in volume due to reinforcement corrosion. Rust formed due to corrosion at least doubles the volume of iron, causing damages to concrete next to reinforcement. This increase in volume causes cracks in the reinforcement direction. As rusting proceeds, water carrying rust leaks out and color of rust begins to appear on crack surfaces. Then, damages due to reinforcement rusting can be easily detected. Later, depth of concrete cover is totally lost and the reinforcement itself will be seen. Usually, rusting is on the surface at the very beginning of the process and the back of reinforcement is sturdy. If cross-section of the material is intact, rust can be cleaned and reinforcement can be fixed by using repair mortar. In the collapse of many buildings, loss of bond strength due to corrosion of reinforcement elements is the main factor. However, this phenomenon cannot be detected in collapsed buildings because ground floor is part of the wreckage in most of the time.

7) **Metallic coatings:** Metallic coatings can be applied to surfaces by hot-dipping, electro-coating, diffusion and mechanical coating. In practice, zinc or aluminum is the most used material against corrosion [5].

8) **Cladding:** In cladding, sheets next to shaft and plate are welded based on their damage level and load-carrying capacity [6].

9) **Painting:** Paint is a suspension-emulsion system having colored solid materials reflecting light and forms a thin elastic layer when dried out [7].

1.7 Repair after corrosion

Corrosion damaged concrete can be cleaned and patched with a high quality concrete. Corrosion damaged reinforcement can be welded or jacketed. Those are some applications, which can be applied on corrosion damaged surfaces.

2. Damage detection

Damage detection is a very crucial step in pinpointing corrosion related problems in buildings and should be done as follows [8].

1. Each element in the building should be clearly coded,
2. Each element should be carefully and thoroughly inspected,
3. The location and number of reinforcements; the thickness of coating concrete should be examined using a magnetic device; cross-sectional loss due to corrosion in certain regions of reinforcement should be determined,
4. Non-invasive measurements should be made on all elements using ultrasound and Schmidt concrete test hammer,
5. After detecting location of reinforcement, core samples should be taken from certain regions provided that reinforcement is not totally cut,
6. Half-cell potential of elements should be measured using a standard electrode; the detected value should be compared to what is given for corrosion potential in International Standards; corrosion level of reinforcements should be determined,
7. Carbonation depth in core samples should be determined by spraying phenolphthalein on samples,
8. Should a building in seashore be investigated, piles, water-sand separation region, part (building) under water, capping-pile intersection, capping, part under and above the deck should be web-cam recorded, damaged regions should be detected using web cam, regions from which samples and measurements will be taken should be determined,
9. Using a hammer, concrete samples should be taken from piles and certain regions,
10. Samples from different depths from sea water should be taken for further analysis.

3. Results and Suggestions

- ✓ When studying strength of structural elements and materials subjected to unsuitable environmental conditions, experiments are carried out under controlled conditions in a lab environment. Appropriate corrections factors have to be used for these experimental results, since they will not simulate real time conditions.

- ✓ Research on corrosion of reinforcement materials has recently been on the rise and experimental methods have been developed to this end. These experiments are very costly and detection after corrosion damage is time consuming and expensive. Therefore, it is suggested that preventive measures against corrosion be taken to decrease cost associated with it.

- ✓ To increase level of confidence in corrosion experiments, adequate number of samples should be taken by using appropriate statistical tables.

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