



Invited Paper

## Material Deficiencies of Reinforced Concrete Structure of Botas Petrol Platform

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### Abstract

Petroleum produced in Turkey, which is exported from Iraq by Kerkük–Ceyhan Pipeline and Azerbaijan by Bakü-Ceyhan Pipeline is exported to world at BOTAŞ Plant. Reinforced Concrete (RC) platform of the plant has significant structural and material problems. It has been found out that some RC pile columns have been losing their bearing capacity. Since concrete used in the structure was not designed to resist sulfate and salt effects, observations have revealed that columns and beams were damaged due to these effects. If the necessary precautions are not taken as soon as possible the structure is likely to complete its economical service life in the near future. The structure needs to be repaired and strengthened. This paper presents some technical suggestions to overcome the problem.

**Keywords:** Concrete; Steel reinforced concrete, Erosion; Corrosion.

### 1. INTRODUCTION

High content of free lime (CaO) and free magnesia (MgO) cause expansion in concrete. Reactions in concrete between C<sub>3</sub>A component of cement and sulfates cause cracking of concrete due to expansion [1]. Ammonium, calcium, magnesium and sodium sulfate are the most hazardous chemicals for cement and concrete [2]. The sulfates cause expansion and strength loss in concrete [3]. Cements with low “three-calcium aluminate content” or cement with proper pozzolanic properties must be used to stop such unwanted effects. By adding some pozzolans to the mixture instead of cement, three-calcium aluminate ratio is reduced indirectly and new components are formed that react with lime and eventually fill the pores in the concrete [4]. Moreover, sulfates in seawater are the main reason for the corrosion of steel in reinforced concrete [5]. Petroleum carried by Kerkük-Ceyhan and Baku-Ceyhan pipelines and that produced in Turkey are distributed from BOTAŞ plant to some other countries. RC platform in this plant suffers from corrosion, cavitations and some vital structural problems. If the necessary precautions are not taken as soon as possible, the structure is much likely to complete its economical service life in the near

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future. Since concrete used in the structure was not designed to resist sulfate and salt effects, damaged parts were observed in the columns and beams. Besides, some of the reinforcement bars in concrete have severe corrosion problems. The structure needs to be repaired and strengthened. The problem could have been overcome by the use of concrete with some admixtures, which provide high durability and more protection against corrosion. In the production of concrete that would come into contact with seawater, special cement types and concrete admixtures should be used.

In this study, structural damages and corrosion of the reinforcement in the BOTAŞ platform are investigated. The plant is located at Iskenderun Gulf in north-east part of the Mediterranean Sea in southern Turkey. Geographical Map of the studied region is given in Fig. 1 and general view of the pier is given in Fig. 2. BOTAŞ-Dörtyol platform structure is 1320 m in length. Pier has two parts: the first one is loading and rail transport platform, the other is the part used to load tankers up to 65000 tons of gross weight.

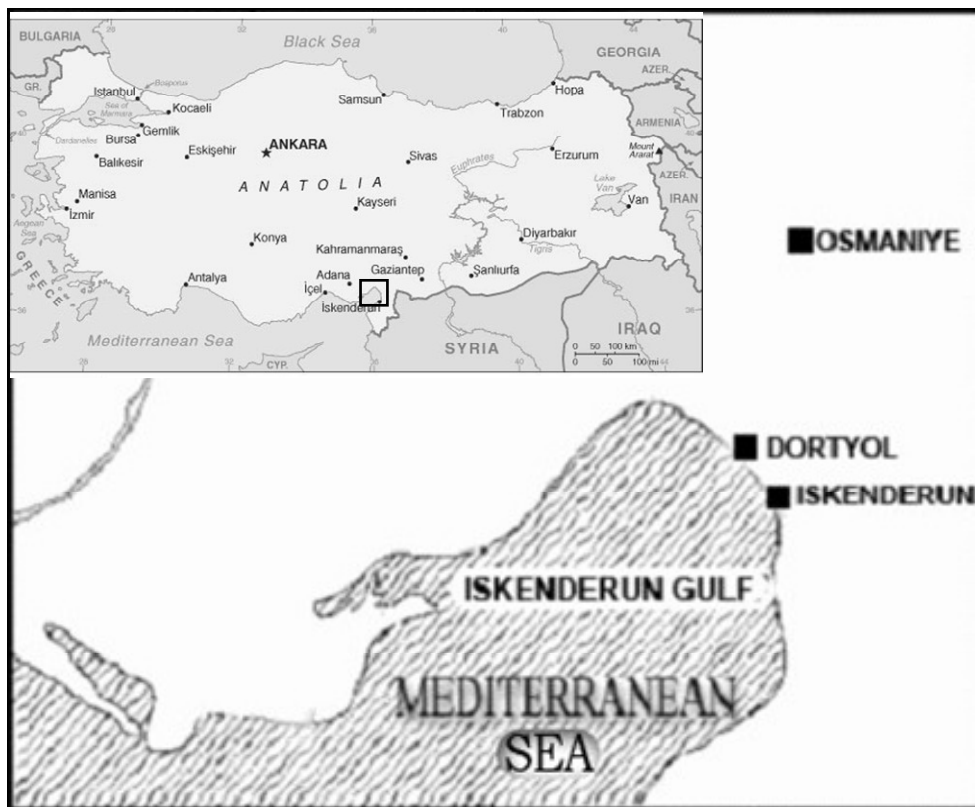


Fig. 1. Map of the region

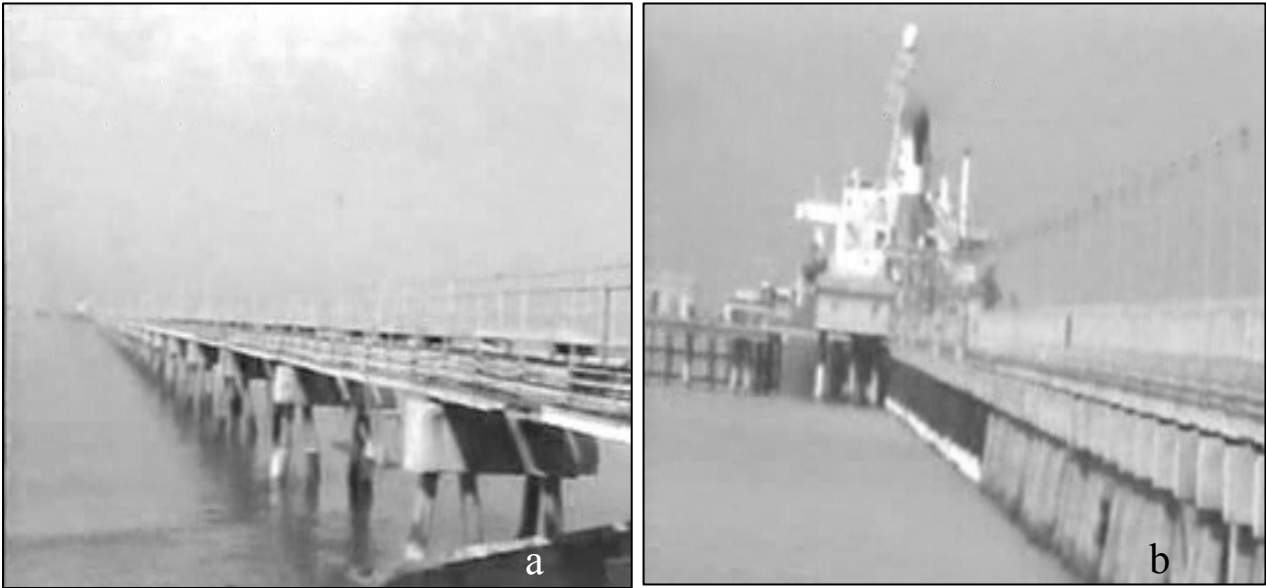


Fig. 2. a& b) General layout of the piers

## 2. METHOD

### 2.1 Investigation of Structural Damages

RC members of Dört Yol petroleum loading pier have suffered from serious structural damages (See Fig. 3. to Fig. 9.). In design practice of RC structures tensional strength of the concrete is usually ignored and longitudinal reinforcement bars on tension side carry tensional stresses. Therefore, reinforcement bars carrying tension loads should be prevented from external effects like corrosion through whole service life of the structure. However, in the investigated structure, these bars corroded heavily as seen in Figs. 3 and 4. Due to loss in reinforcement area, flexural capacity of the sections significantly reduced. As a result, beams may fail even under normal dead and live loads, without being subjected to a dynamic loading such as earthquake.



Fig. 3. Some damages in a beam

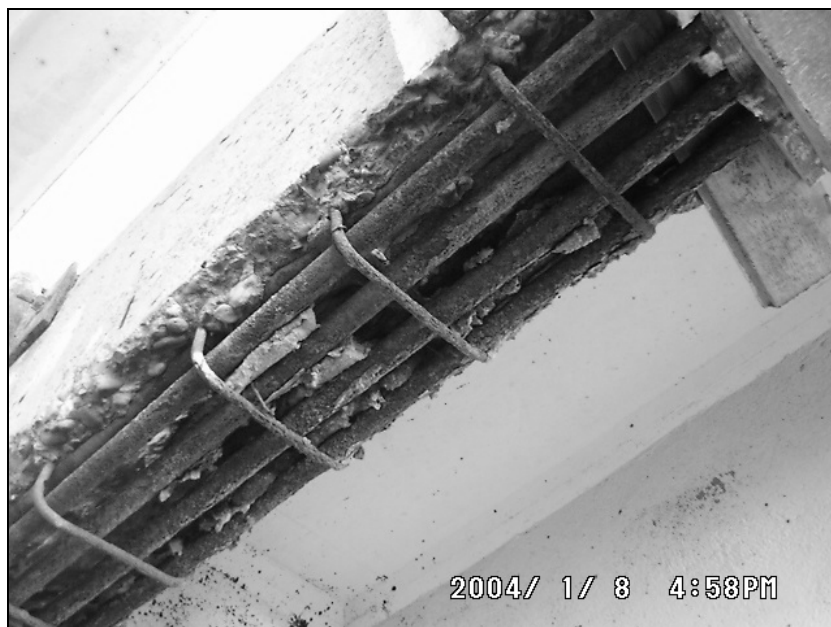


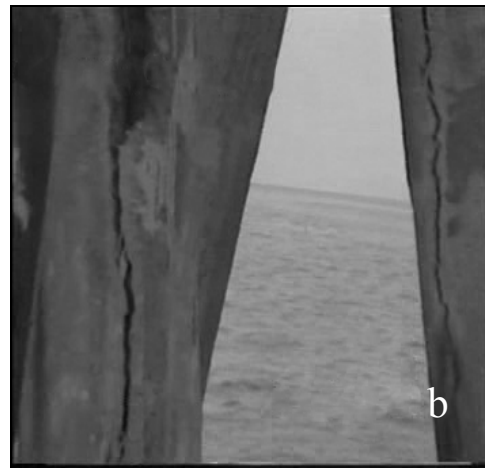
Fig. 4. Concrete damage and corrosion of uncovered reinforcement bars at a beam element



Fig. 5. Concrete damage at beam faces.



Fig. 6. Separation of concrete at beam faces



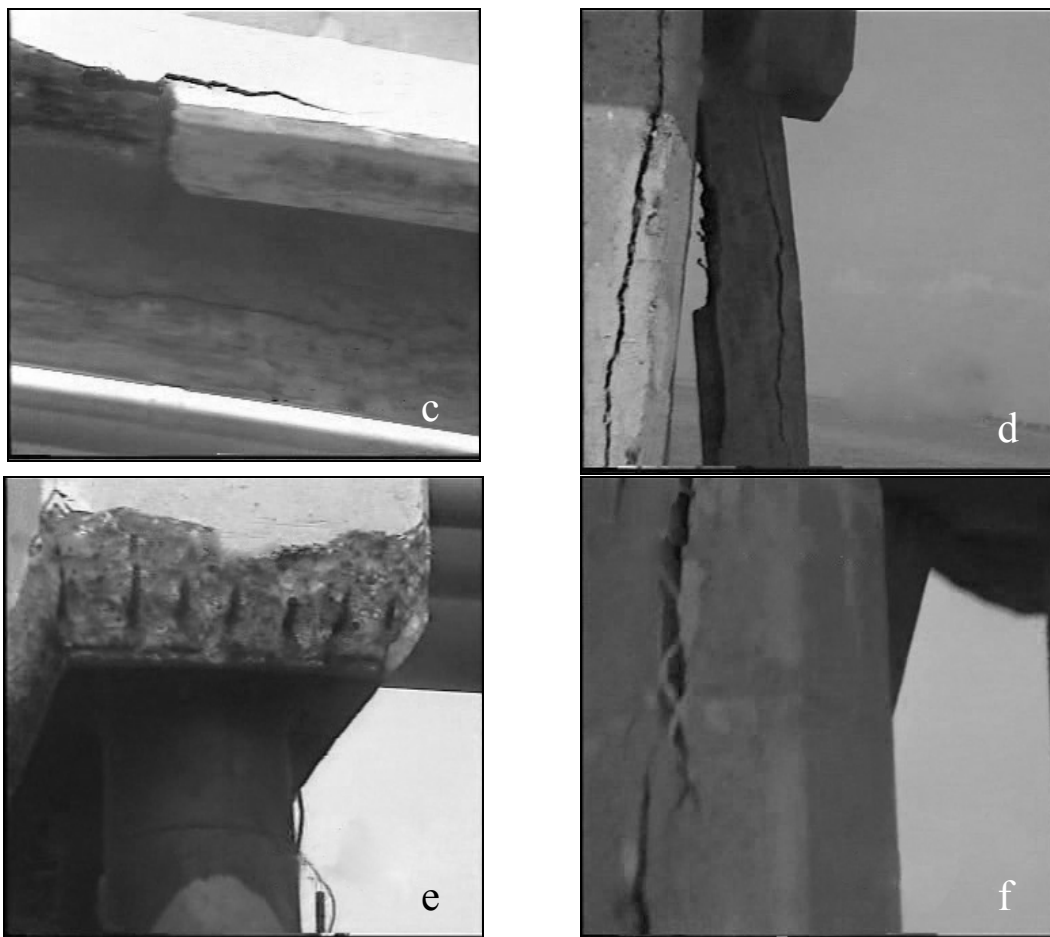


Fig. 7. Corrosion and structural damage in RC piles near to sea surface,  
a, d & e) Longitudinal cracks.  
b) Damage in the pile.  
c) Transverse cracks.  
f) Reinforcement separated from concrete

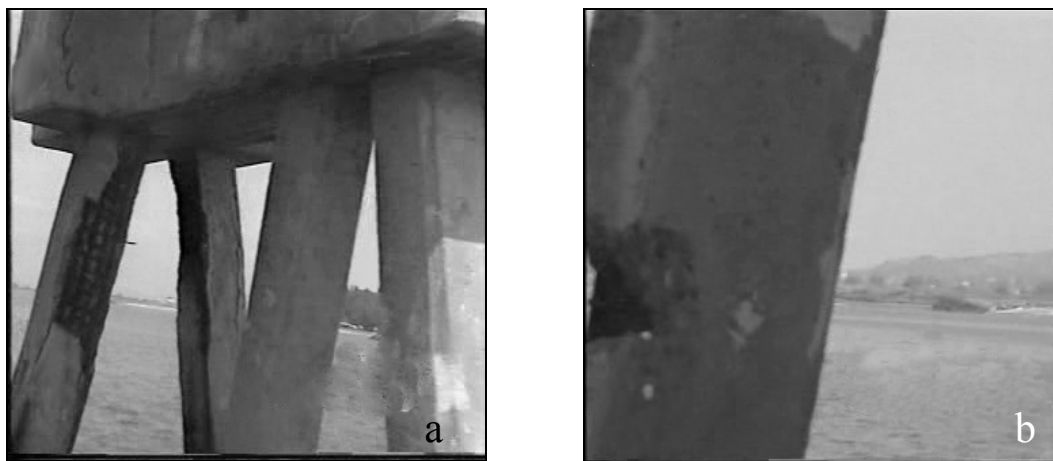




Fig. 8. Corrosion and structural damage in RC piles near to sea surface  
a) Damage in two piles.  
b) Concrete fall down and reinforcement corroded.  
c) Longitudinal cracks in a beam.  
d, e & f) Serious damages in beams



Fig. 9. Corrosion and structural damage in RC piles

## 2.2. Corrosion of Reinforcement Bars

Corrosion is a process of chemical and electro-chemical reactions eventually causing metals to lose their mechanical properties. Especially steel bars are not resistant against effects coming from water and atmosphere [6]. Some RC elements in BOTAS-Dörtyol petroleum platform pier suffering from corrosion are given in Figs.10-13.

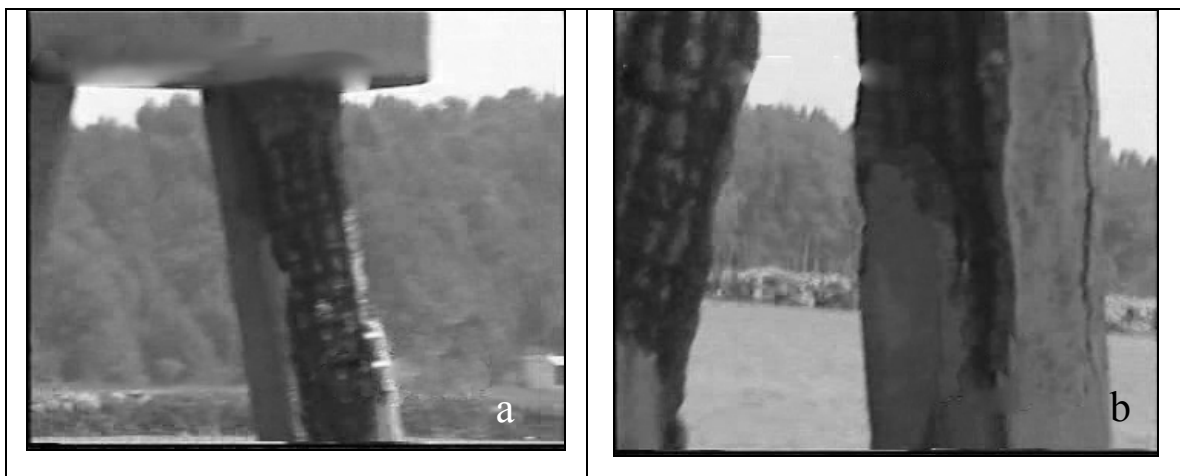
## 2.3. Compressive Strength of Concrete

Compressive strengths of the concrete samples taken from the piles, platform and beams were measured by the core test. Compressive strength values measured are given in Table 1.

**Table 1.** Compressive strength of concrete at different structural elements

Structural Element	Compressive Strength ( MPa)	
Pile	1	30
	2	42
	3	50
	4	35
	Average:	39.2
Platform	1	40
	2	45
	3	50
	4	42
	Average:	44.3
Beam	1	50
	2	52
	3	48
	4	55
	Average:	51.2
Overall average:	44.9	

Studying the compressive strengths of samples, it can be seen that strength of the concrete ranges from 30 MPa to 55 MPa, and average strength is 44.9 MPa. These results have indicated that the strength of the concrete was lower than that required by the standards.





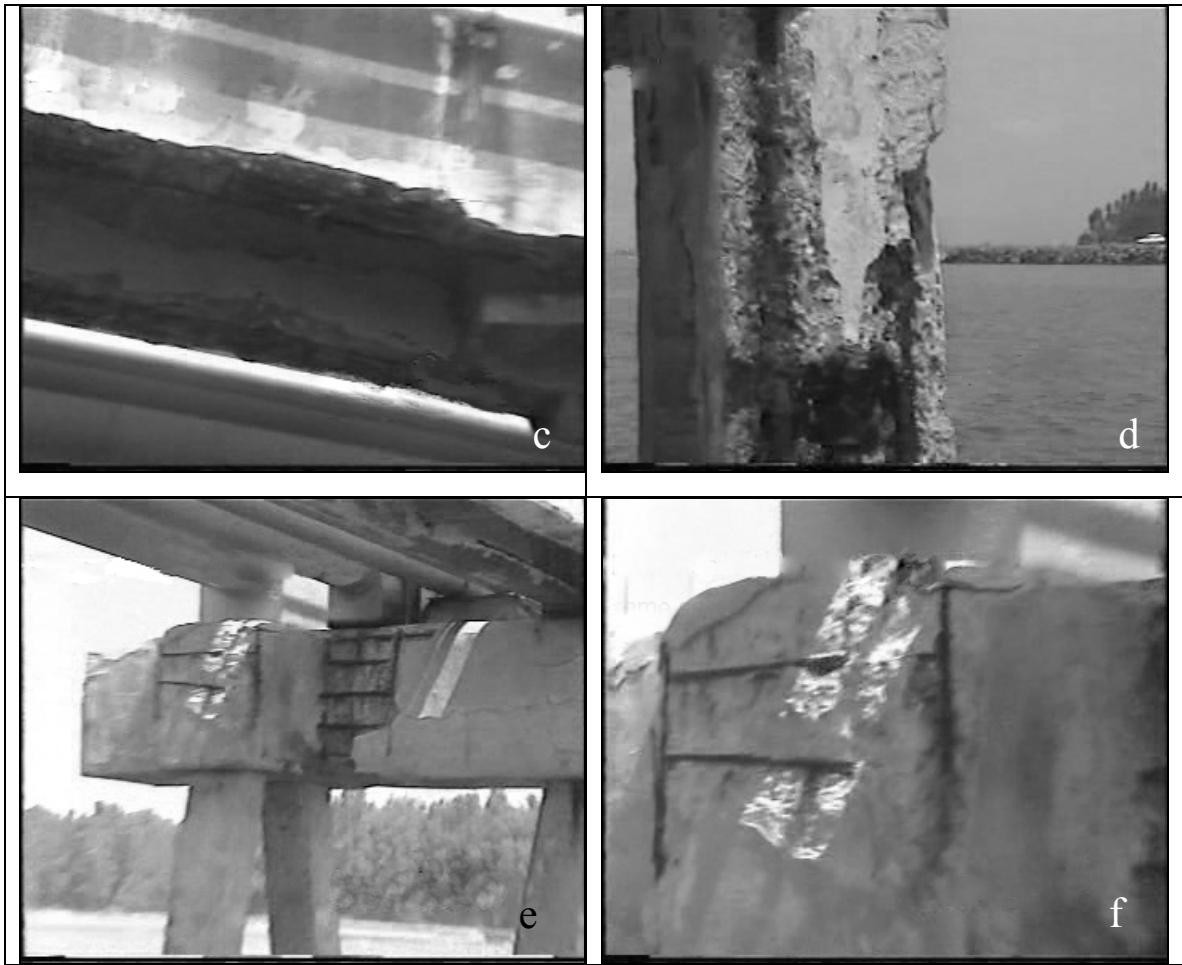


Fig. 10. Covers of concrete beams have fallen completely.  
a, b, c & d) Corrosion and structural damage in piles.  
e & f) Damage in concrete and corrosion of the reinforcement bars.



Fig. 11. Cover of concrete has fallen and the reinforcement is corroded heavily.



Fig. 12. Corrosion in RC piles



Fig. 13. Corrosion in RC beams

#### 2.4. pH and Chlorine Contents

pH values and chlorine content of the seawater have been determined and given in Table 2.

Table 2 pH Values and Chlorine Content

Sample	Sample weight (kg)	Amount of water (gr)	pH value	% Chlorine content
Dörtyol MD7W Dolfen	3	14	9.2	0.406
Dörtyol MD7E Dolfen	2.6	14.2	11.1	0.560
Dörtyol MD2E Dolfen	3.5	15	11.6	0.650
Average:	3.03	14.3	10.7	0.538

pH values found by tests are between 9.2 and 10.7. In places, where pH is less than 10, corrosion process continues in steel bars. pH values above 10 mean corrosion process just started. Chlorine content changes have been found in the range of 0.406 % to 0.650 %. However, upper limit for chlorine content is 0.2 % [6]. High chlorine content must be one of the reasons of corrosion. The alkalinity of the concrete, permeability of the concrete cover, the quality of the concrete and the corrosion environment were crucial factors in influencing the effectiveness of the concrete cover for corrosion protection of reinforced steel [7].

### 3. RESULTS

Results obtained from this research are listed below:

1. Compressive strength of the concrete changes between 30 to 55 MPa, and the average compressive strength is 44.9 MPa. These results have indicated that the strength of the concrete used is not so important as its durability.
2. Reinforcement bars in the piles are corroded heavily and they are still under the effect of corrosion. This also caused a significant reduction in sectional capacities.
3. pH values obtained have the average value of 10 in beams and piles. However, it is lower in upper portions of structural elements, meaning corrosion process is going on.
4. Volume expansion in the reinforcements caused wide cracks in the concrete. Due to severe corrosion effects combined with cavitations and freezing-thawing, the covering concrete is completely damaged in some elements.
5. If remedial works are not started quickly, structure may complete its service life in the near future.

### 4. CONCLUSIONS AND SUGGESTIONS

In the present study, the structural and material problems of an important petroleum platform in Turkey were investigated. It was observed that the durability of the concrete caused corrosion, sulfate and cavitation effects. The structure is a good example showing that durability does not depend solely on the strength of the concrete but also on its composition.

Although, the compressive strength of the concrete samples was above 30 MPa, due to its poor composition of the concrete could not resist against severe effects. It is a well-known fact that the causes of damage in concrete are freezing-thawing, water penetration, chemical degradation and cavitation [8]. Therefore, it is important that the durability of concrete be enhanced. This can be accomplished by some additives which improve the properties of both freshly mixed concrete and hardened concrete by

pozzolanic reaction. Benefits of using additional binder materials on the durability of concrete are well established [9- 11].

The existing structure has to be strengthened to resist service loads and probable lateral loads such as earthquakes or winds. However, before the strengthening phase, damages should be repaired to improve structural performance of existing elements. For this reason, concrete surfaces should be washed by pressurized water. Then, the chlorine ions that have penetrated into the concrete should be removed from concrete through electro-chemical methods. Next, the reinforcements must be cleaned and covered with corrosion resistant epoxy material that can provide bond between steel and concrete. Before epoxy gets dry, fixing mortar must be placed and granular fine basaltic sand must be sprinkled.

Corrosion and sulfate resistant cements, basaltic pumice and ground blast furnace slag should be used on cleaned reinforcement and concrete mortar surface. In case of inadequacy of sectional capacities, new reinforcement bars should be added to the structural elements or their capacities should be increased to desired level by other strengthening methods such as FRP wrapping.

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