Structural rehab in Portugal...

The Setenave Dry Docks Rehabilitation

by Ivan Ramalho de Almeida, Thomaz José Ripper Barbosa Cordeiro, and José Paulo Veríssimo Maia Costa

Setenave is a general designation for a shipyard built in the early seventies, at the right shore of the Sado River, south of Lisbon, in Portugal. In 1991, an important structural rehabilitation of the reinforced concrete walls of the Setenave dry docks was performed. Repair was required to overcome the problems of generalized reinforcement corrosion, then evidenced by disaggregation of very large areas of the concrete cover (Fig. 1).

The reinforced concrete walls of the dry docks — constructed as semi-buried tanks, about 75 x 900 m (250 x 3000 ft) in plan — are nearly 1 km (0.6 mi) long, about 11 m (36 ft) high in the part designed for ship construction, and 22 m (72 ft) high in the ship repair area. The bottom of those areas lies at about 2.0 and 12.5 m (6.6 and 41.0 ft), respectively, below sea level (Fig. 2).

The area of repair is subject to weekly filling and emptying cycles, whereas the construction area is filled two or three times a year.

Evaluation

Simple visual observation of walls evidenced the intensity of structural concrete disaggregation (which reached more than 10 m^2 at some places) and the resulting exposure of corroded reinforcement. A preliminary quantification of damaged areas supplied the following data:

- total area to be rehabilitated: 25,000 m^2 (269,000 ft^2);
- mean depth of intervention: 10 cm (4 in.);
- volume of concrete to be replaced: about 2500 m^3 (3300 yd^3).

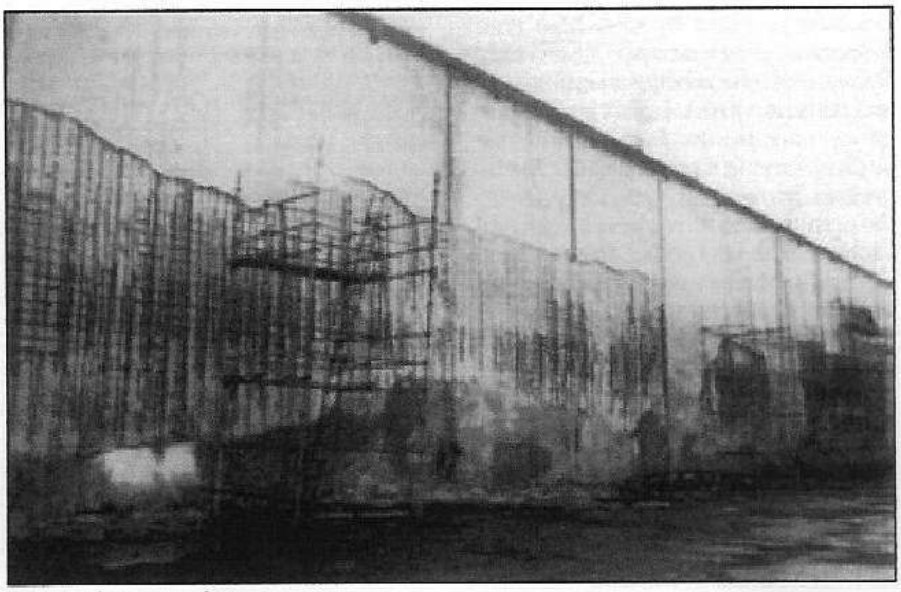

Fig. 1: Concrete disaggregation

In mid-1991, this job was one of the most important structural rehabilitation works in progress in the world.

Investigation and testing

To quantify the causes for degradation, several in-situ and specialized laboratory tests[1-3] were carried out, which gave the following indicators:

1) Composition of original concrete:

- water-cement ratio (*w/c*): 0.63;
- cement proportioning: approx. 300 kg/m^3 (505 lb/yd^3);
- type of aggregate: limestone and siliceous sand;
- mean compressive strength of concrete: 24.6 MPa (3570 psi);
- estimated f_{ck}: 18.0 MPa (2600 psi).

2) Chloride determination:

- The investigation showed the presence of chlorides through diffusion, reaching values at the reinforcement level up to 0.3 percent of concrete mass.

3) Sulfate determination:

- The values detected showed that the amount of sulfates in the concrete mass was not important.

4) Depth of carbonation:

- Depth of carbonated concrete was always less than depth of reinforcement cover.

5) Investigation of leakage currents:

- The result was negative in spite of the presence of winches, traveling cranes running on rails, lighting poles, a transformer substation, and welding shops located nearby.

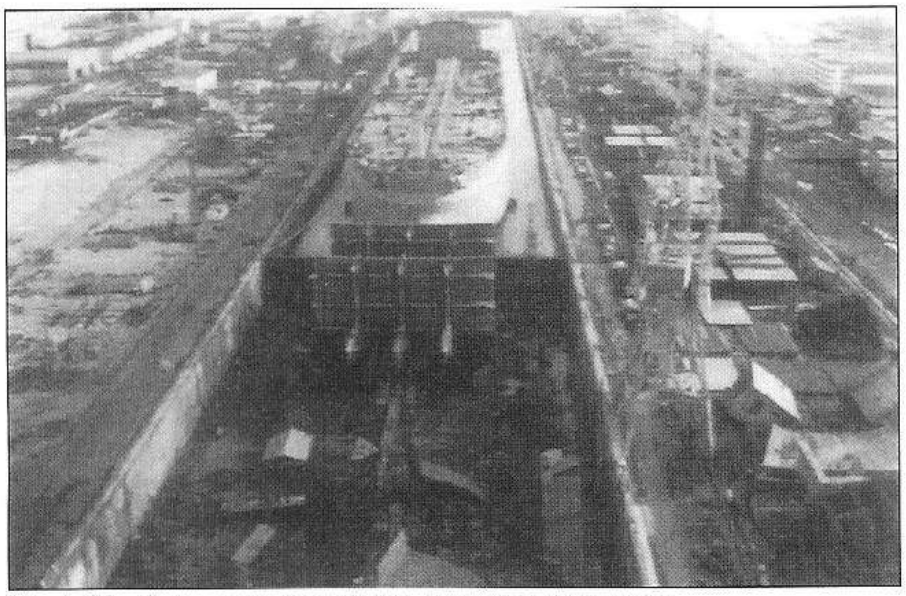

Fig. 5: The docks, again in operation, after the rehabilitation

cepted by the owner; in fact, though some parameters as defined in the specifications had not been obtained, such as the case for permeability — in which case the water penetration was higher than 10 mm (0.4 in.), but less than the cover thickness — the overall quality of the service was considered very good.

Monitoring procedure

In-situ tests are expected to be carried out every year to determine the following:

- the penetration profile of chlorides,
- depth of carbonation,
- surface permeability, and
- corrosion capacity.

The purpose of these tests is to check the specifications used and the work done to ensure structural durability.

Conclusions

The main conclusions that can be derived are as follows:

- The use of a rational shotcrete proportioning procedure was successful. A very technically accurate and economically profitable result was achieved.
- It is possible to obtain high-performance shotcrete with current materials and conventional shotcreting techniques and equipment, without any sophistication or change in procedures.
- The composition of the concrete used in this work involved low cement and low CSF consumptions, in spite of the fact that the concrete exhibits high mechanical strength and prospects of high durability.
- Encouraging results were always obtained, largely exceeding the requirements.
- The good results obtained were certainly due to the careful attention given to the structural rehabilitation procedure from the start. A valuable output has already been obtained: the development of a pilot technology providing excellent technical results, and the reopening of the normal operation of the docks (Fig. 5).

Moreover, the philosophy of service adopted in this work is expected to be useful for a long time, both with regard to the durability and integrity of this structure and in future applications.

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***Ivan Ramalho de Almeida** is a full professor of construction materials at the Universidade Federal Fluminense, Niteroi, State of Rio de Janiero, Brazil. He is a graduate civil engineer and holds a master's and a PhD degree in civil engineering.*

***Thomaz José Ripper Barbosa Cordeiro** is a professor of concrete design at the Universidade Federal Fluminense, Niteroi, Rio de Janiero, Brazil, and an independent consultant in Lisbon, Portugal, in the strengthening and repair of concrete structures.*

***José Paulo Veríssimo Maia Costa** is the Chief of the Department of Structural Rehabilitation of Armol-Freyssinet, in Lisbon, Portugal.*