

Structural rehab in Portugal...

The Setenave Dry Docks Rehabilitation

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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 m² 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 m² (269,000 ft²);
- mean depth of intervention: 10 cm (4 in.);
- volume of concrete to be replaced: about 2500 m³ (3300 yd³).

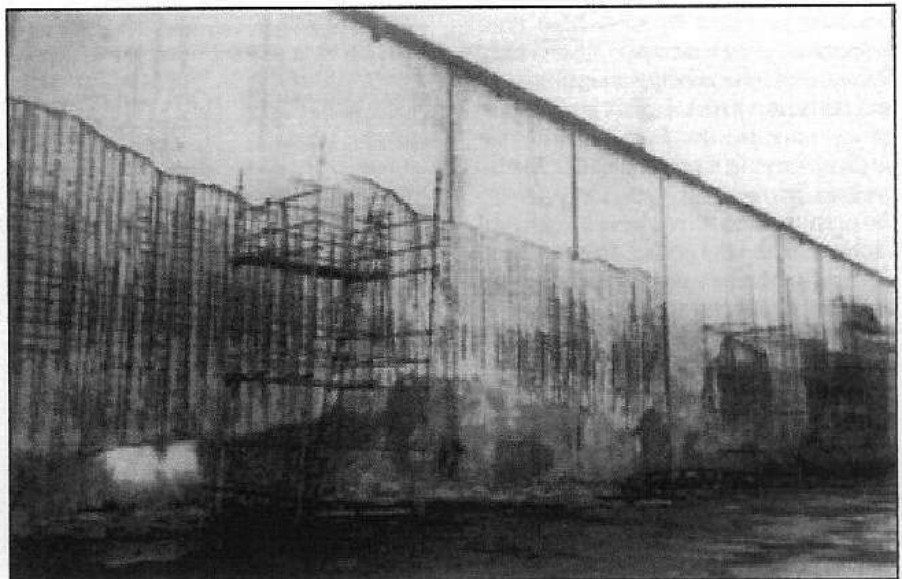


Fig. 1: Concrete disaggregation

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 tests¹⁻³ 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/m³ (505 lb/yd³);
- 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.

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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 re-opening 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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Acknowledgments

The authors would like to thank CAPES/MEC, CNPq/SCT (Brazil) and LNEC (Portugal) for the support provided in carrying out this work.

Selected for reader interest by the editors.

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