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3. Grain Silo of Trafaria (Portugal)

Owner: *Silopor*
Design: *V. Coias e Silva, Guy de Castro (foundations) and Gapres (dynamic studies)*
Construction: *Engil*
Date of completion: *August 1984*
Duration of the works: *three years*

Introduction

With its 2000000 kN storage capacity, the Trafaria grain silo is the largest in Europe and one of the largest in the world.

The silo and its auxiliary plants are located at the center of a large platform reclaimed on the south bank of the Tagus using the sand dredged from the river bottom in the manoeuvring and docking areas (fig. 1). This group of buildings make up the nucleus of the terminal, where the grain is stored and the main equipment for its reception, weighing, recirculation, distribution and dispatching is installed.

This group is comprised of the following reinforced concrete buildings:

- The silo itself, consisting of four blocks of bins 72 to 76 m high, designed to the storage of grain and related products
- The main intake tower, 82 m high, housing eight elevators
- The weighing center, 39 m high, where the automatic weighers are installed
- The outloading tower, 48 m high, adjoining the weighing center, where the outloading and recirculating elevators are located
- The control building, 22 m high, accommodating the control system of the whole terminal
- The road outloading silo, 42 to 49 m high, consisting of outloading bins, weighers and loading tunnels, for bulk loading of lorries.

The overall concept is one of functional de-centralization into separate buildings, in order to ensure reduced vulnerability to accidents like explosions or fires.

Other determining factors were, however, brought into play, reflecting themselves in the general design of this cluster of buildings: The use of slipforming – common to all of them –, the employment of precasting techniques, and the constant preoccupation with safety, as, for instance, in avoiding the restriction of explosion-prone equipment.

The two larger buildings, i.e. the silo and the intake elevator tower are briefly described herein, emphasising particularly the structural aspects involved.

Geotechnical conditions

The silo and its auxiliary buildings were sited on an area where the miocenic substratum presents a platform, around 16.0 m deep in relation to the hydrographic zero, slightly downstream of the fossile valley.

Above the −16 m level only two formations exist: From −16 to 0, beach sand; and from 0 to +6 m, the approximate elevation of the reclaimed of the reclaimed platform, the dredged sand.

Silo

In its basic design, fig. 2, the silo consists of circular bins tangent along four orthogonal generatrices called main bins, the «ace of diamonds» or interspace bins also being used for storage. The silo is made up of monolithic batteries or blocks of bins, in patterns of 3×3 or 4×4, structurally independent from each other. Altogether there are six of these silo blocks, comprising two basic sizes of circular bins: 10.1 and 7.55 m in diameter. The typical organization of the silo along its height is also shown in fig. 2.

The foundations of the silo blocks consist of rectangular cast «in situ» reinforced concrete piles, transfering the vertical loads to the miocenic substratum.

The main feature taken into account in the structural design was the seismic action. The Lisbon area being highly earthquake-prone, this aspect had to be studied with particular attention.

Two different methods were followed to establish seismic coefficients: One based on the structural actions code, at the time under revision and updating, the other using the recorded spectrum of the earthquake that occurred in Lisbon in February 28, 1969. Two levels of seismic action were taken into account, corresponding to return periods of 1000 and 100 years. The peak accelerations considered were 150 and 75 cm/s^2, respectively.

The dynamic analysis showed that the method based on the record of the 1969 earthquake yielded in all cases more unfavourable member loads and displacements. The structure-foundation interaction was also taken into account for different hypothetical behaviours of the sandy overlay.

Other relevant structural action that was suitably analysed was that of the bulk products to be stored inside the bins. These ranged from plain wheat to feed meals, with widely varying pressure conditions. Particular attention was given to the bins subject to simultaneous loading and extraction of product, a situation that gives rise to increased pressures.

Intake tower

Square in layout, with a side of 19.5 m, the intake tower has a total height of 82 m, and houses the eight grain elevators (fig. 3). The walls facing East and West possess large openings shuttered with lightweight acrylic sheeting, intended to provide quick pressure relief in case of grain dust explosion. The inside floors also present large cutouts to avoid the undesirable restriction of the building interior. In fig. 3 another three of the above mentioned buildings appear: The weighing center and the adjacent outloading tower, and the smaller control building.

(V. Coias e Silva)

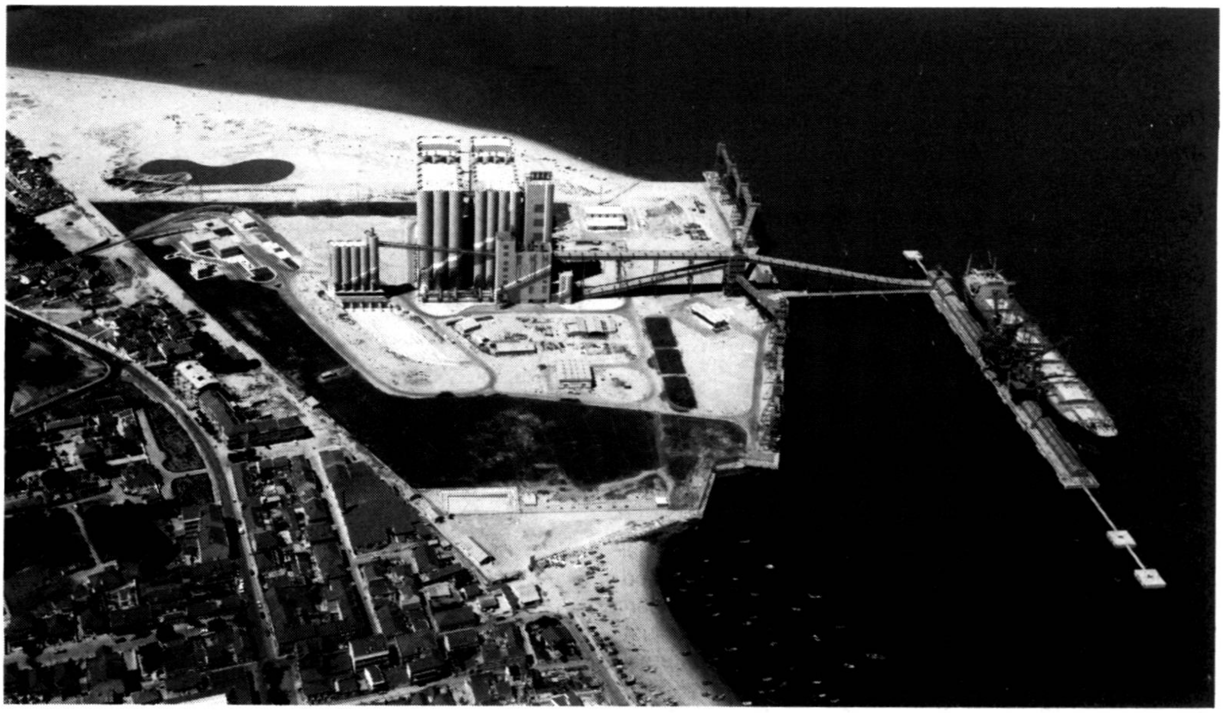

Fig. 1: Grain terminal of Trafaria – General view

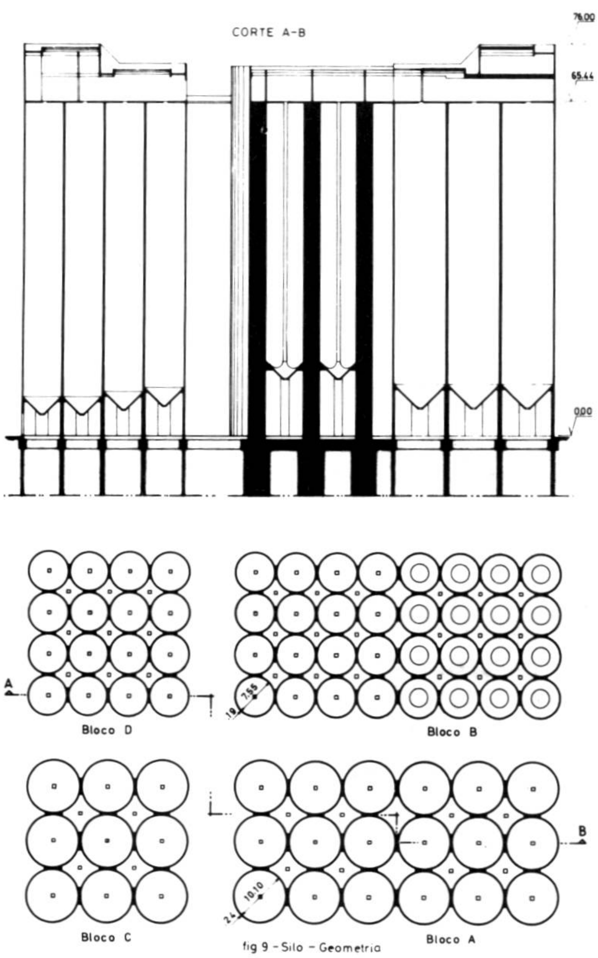

Fig. 2: Silos – Geometry

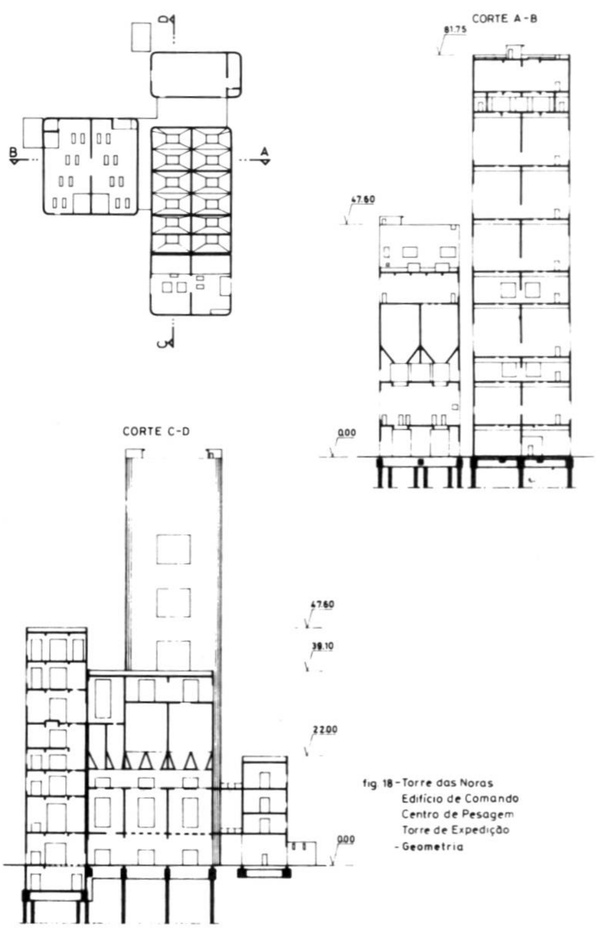

Fig. 3: Intake tower, control building, weighing center and outloading – Geometry