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PROPOSALS FOR CONSOLIDATION AND REPAIR OF TWO GRAIN SILOS

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Abstract: *The paper presents the behaviour of some reinforced concrete grain silos, in service for more than 40 years respectively. All of these silos have suffered multiple durability deteriorations for which an in-depth inspection was performed. Studies focused on diagnosis and level of deteriorations, on rehabilitation and strengthening. A decision as to level of intervention took into account the estimated remaining service life of each silo. The paper deals with the practical application of repair and strengthening method.*

Key words: *rehabilitation, concrete silos, diagnosis, strengthening.*

1. Introduction

The paper presents two cases of grain silos made of reinforced concrete and having cylindrical cells.

The first grain silo from Calarasi storage, presented in the Figure 1, base built 45 years before the inspection. It is composed of four batteries with total 42 cylindrical cells, one cell of 7 m in outside diameter and 36 m in high, 36 pockets cells and 20 stellate cells with the wall thickness of 18 cm. The slip form method of construction was used [1].

Fig.1. *Calarasi silo*

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The second silo from Dragos Voda storage, presented in the Figure 2, base built 40 years before the inspection is composed of one battery with 6 cylindrical cells, one cell having a diameter of 7.30 m and 20 m high, with a wall thickness of 15 cm. Two stellate cells are formed between the cylindrical cell walls.

An in-depth inspection was performed for each silo, followed by a diagnosis of deteriorations identified and recommendations for rehabilitation and strengthening.

The practical application is presented with the focus on repair and strengthening methods and recommendations are made as to inspection intervals [2].

Fig. 2. *Dragos Voda silo*

2. Calarasi Cylindrical Cells Silo

The silo has the purpose of storing grain with a total storage capacity of 50,000 tons.

Following the examination of the silos, damage and degradation were observed in a significant number of cells, from which 19 circular outer cells and 11 pocket cells were investigated.

Examination of the cells in height was performed using the nacelle. Multiple deteriorations, mainly affected the concrete cells wall, having an advanced state of cracking and numerous deficiencies [3].

An in-depth inspection was performed using climbing platforms for access to both sides of wall, including internal one and was made including hammering the concrete and removing the detachable or broken layer of cement mortar and detecting the entire zone of damaged concrete.

The examination started from the signs of visible deteriorations, which consisted in developed cracks of more than 0.3-0.7 mm, detached or broken cement mortar and even deep deteriorations of concrete.

The inspection showed deep deteriorations in concrete, multiple local small deteriorations, such as cavities, holes (some of them pierced), detached bars cover, inconsistent concrete, unfilled holes provided for slip form supporting bars figure 3.

On one of the cells a repair was attempted about 20 cm on the wall height and about 3m long on the cell circumference. The repair was accomplished by filling with concrete

from the inside and sheet metal formwork on the outside. At this intervention it was found that the filling concrete did not adhere to the old concrete, there being a separation plan between them. Also the area is crossed by cracks with 0.7 mm openings, extended beyond the repair.

Fig. 3. *External cell surface before inspection*

At the bottom of another cell there is a limited but profound deterioration. Here, the brittle concrete has been cleaned due the weather, leaving a horizontal bar a few free vertical bars. These bars show advanced corrosion and loss of adhesion to concrete.

The class concrete in cells wall was C16/20 but unfortunately with defective. The main damages found were:

- local cavities or casting interruptions like Figure 4;
- cracks caused by the perforations in the walls practiced for temporary windows and ventilation pipes;
- segregation areas or lack of compactness;
- the emergence of vertical and horizontal reinforcements, with friable concrete, caverns and wall piercing inward, marking an error of concrete sliding, Figure 4.

Fig. 4. *Local cavities and in-deep reinforcement corrosion*

These deficiencies were the main cause of the further deteriorations, such as:

- friable or expelled concrete, concrete settling;

- cracks, deformations;
- reinforcement corrosion (not active).

The defects and deteriorations may further adversely affect the structure function and its strength and stability.

The proposed strengthening method in similar cases was to cast an interior reinforced concrete layer, i.e. a supplementary reinforced concrete cell, but in this case the application of an interior concrete layer to each cell implies a lot of concrete and steel, with high costs.

For the actual state of deteriorations and having in mind the repair and strengthening cost reduction, a restoration of the structural concrete continuity was considered alternatively as a limited repair or strengthening, adequate for an additional shorter service period (for a further 25 years) but whit lower expenses.

For the structural concrete repair and strengthening, we recommended different procedures, using special reliable chemical products which become available in the country at the time.

So, for filling of all the cavities or holes, the concrete mix of concrete class C20/25 included aggregates of to 3 mm or 7 mm, an acrylic bonding agent to be applied on old concrete surface and a super plasticizer, so as the concrete vibrating became not needful.

Other small deficiencies of the concrete, as well as of the reinforcement concrete cover, were repaired using epoxy bonder or epoxy concrete. The cracks exceeding 0.3 - 0.5 mm were injected using low viscosity epoxy resin like Sure-Inject, Day-Chem Ar Bond or Acrylic latex agent [4-7].

3. Dragos Voda Cylindrical Cells Silo

The silo has a capacity of about 4000t, has been designed to complement the capacity of another existing silo. It has a single cell battery and uses the adjacent silo machine tower. Between the two silos there is a passageway, articulated by them.

The main deteriorations of this silo were observed to concrete and reinforcement on external cells surface only see Figure 5.

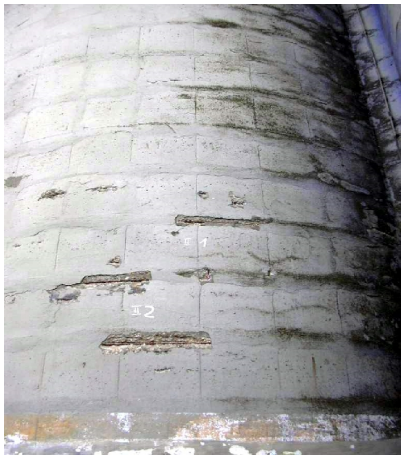

Fig. 5. *Deteriorations on external cell surface*

An in-depth inspection was performed using a kind of nacelle crane used for access on electrical poles, removing the detachable cement mortar.

The main concrete and reinforcement deteriorations were observed only on the outer side of the cylindrical walls, especially at form panel joints and they consisted in:

- detachments of the reinforcement concrete cover ,where the thickness measured 5-15 mm;
- segregation areas;
- adherent or in-deep corrosion of the reinforcement in this zone;
- concrete deterioration due to freeze-thaw, see Figure 6.

Fig. 6. *In-deep reinforcement corrosion*

After about 40 years in service the Dragos Voda silo showed a good behavior in terms of strength and stability, less in terms of durability.

These deteriorations were caused by the external whether action combined with an insufficient concrete cover of outside layer of the reinforcement and of concrete segregation.

The repair solutions for durability deteriorations were aimed at ensuring the intended remaining service life of the silo.

An evaluation of the maximum load capacity showed insufficient design reinforcement of the two stellate cells and the need for these cells to be filled up to 50% of capacity.

For the repair of structural concrete we recommended different procedures using special, reliable chemical products which became available in the country at the time, such as epoxy bonder or epoxy concrete and an outside concrete surface protection by impregnating it with chemical products: Multi-Purpose Construction Grout or Rapid Resin Repair [8], [9].

4. Conclusions

All silo structures examined have suffered in terms of durability, but no other damages or other deterioration signs from seismic action or differentiated settlements were found.

In the first case of Calarasi grain silo with four batteries of cylindrical cells, made by the slip form method of construction, the casting in slip form of concrete in a cells wall was unfortunately defective, followed by portions of concrete cast in place after the setting strength started, local cavities or casting interruptions, segregation areas (lack of

compactness), impurities, friable and expelled concrete, concrete settling.

The defects and deteriorations may further detrimentally affect the structure function and its strength and stability.

The limited strengthening to reestablish the structural concrete continuity appeared to be a more favorable solution and was recommended for a shorter additional service period and lower expenses.

The use of modern chemical products to provide high bond and strength levels between old and new materials and of completion materials offers a reliable rehabilitation solution for a limited strengthening of grain silo cell, but with assistance from the specialists and by exerting a step by step control.

In the second case, the Dragos Voda storage base silo of 6 cylindrical cells, erected by the stepping form method of construction, showed a good behavior pointing terms of strength and stability, less in terms of durability.

The main concrete and reinforcement deteriorations were located only on the outer side of the cylindrical walls, especially at form panel joints, the main causes being the external whether action along with the insufficient concrete cover of the outside layer of reinforcement and concrete segregation.

For the repair of structural concrete we recommended different procedures using special, reliable chemical products, such as epoxy bonder or epoxy concrete and an outside concrete surface protection by impregnating it with chemical products.

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