ORGANIZATION AND TECHNOLOGY DURING CONSTRUCTION OF CEMENT SILO

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This paper describes main project references during construction of a cement silo that should provide continuous and economic storage of up to 7 types of cement in eight chambers with the total capacity of 20.000 tons. The paper describes organizational issues occurring during construction with application of sliding formwork technology. The need for a detailed planning phase in project is pointed out as well as possible risks during the project. The paper discusses the need for additional human resources and equipment during the application of sliding formwork technology.

KEWWORDS: cement silo, sliding formwork, resources, risk.

INTRODUCTION

One of the major investment projects within Nexe Group Inc. Našice, whose implementation began in 2007 and is still ongoing, is the construction of a silo for storage of cement within the Našicecement Inc. factory in Našice. The need for the new cement silo occurred because of inadequacies of existing storage capacity that did not entirely satisfy the needs of the technological production process. The main objective was to build a facility according to the provisions of the adopted strategy of Našicecement Inc. Našice.

Silo capacity, technical infrastructure, building specifications and project organization have put it in the group of the most challenging construction projects in the wider region. Sliding formwork technology was applied for the construction of silo. The last time this technology was applied in the Slavonia-Baranya region was more than seven years ago, on a smaller project.

Construction of the *Cement Silo No. 6-13* involved two reinforced concrete silos, each with 4 cells, the total capacity of approximately 20,000 tons and the area between the silos for loading bulk cement.

Application of sliding formwork technology demanded implementation of best practices in management of this construction project (Woodward, 1997):

- management of scope - construction project is unique and purpose-made, therefore it has to be fully briefed and designed
- procurement
- planning and progress – analysing the project, setting a plan of action and progress control
- time management
- cost management
- quality management – determination of standards and their observance
- human resources management
- risk management – determination what are the risks, who carry them and how can they be avoided or minimised
- zero accidents techniques.

Construction system - sliding formwork

Sliding formwork sets were developed for high buildings, with closed layout without horizontal structures, with the same or uniformly variable wall thickness by height (tall factory chimneys, grain silos, liquids containers, high columns of bridges, cement silos). Sliding formwork is continuously vertically shifting formwork. This formwork is lifted using special cranes or hydraulic presses (Chudley, 2006).

Continuous movement of the formwork during casting of concrete avoids the adhesion between the surface and the concrete. Casting the concrete is done in layers throughout the volume of the building. At the moment when the coupling of concrete occurs, or when concrete reaches initial strength, formwork is erected to stop the connection between the formwork and concrete.

Assembly of sliding formwork consists of (Lončarić, 1995):
- formwork surfaces - steel sheet metal surfaces on steel substructure, height 1.5-2.0 m, width 1.2 - 2.4 m
- yokes - which accept the load of formwork, materials and labor and transfer its to the hoists
- load-bearing pipes - on which the cranes slide
- slip-pipes - used as protection of load-bearing pipes from concrete and for hardening the load-bearing pipes. Sliding tube is an integral part of the crane.
- measuring equipment - which monitors the height and levels the sliding formwork
- working area - located on the upper edge of formwork
- hanging working scaffolding - which is used for repairs of finished walls and concrete care during the sliding.
- lifting device - self propelled hydraulic cranes, speed range 5-20 cm.

Application of this technology requires a special organization of the building site:
- continuous monitoring of formwork and presses
- continuous work during sliding
- discipline in the work.

In addition to these organizational particularities, application of sliding formwork technology requires continuous work of the laboratory for testing the properties of fresh concrete on the construction site during the sliding process in order to achieve uniform quality of concrete.

Work of the laboratory on the construction site must be coordinated with the work of the laboratory of concrete producers.

Planning the construction of the cement silo

Based on the documentation submitted by the investor, company Našicecement Inc. Našice, contractor approached to the analysis of costs and the bidding process for the execution of construction works on silo. Specified reinforced construction of cement silo required a large engagement of human and material resources, procurement of additional equipment and subcontracting companies specialized for each phase of works.

Next to the target date and the period of realization of the project this required special attention during planning phase of the project. Based on the project documentation and cost estimates detailed financial and operational plans were made (Figure 1).

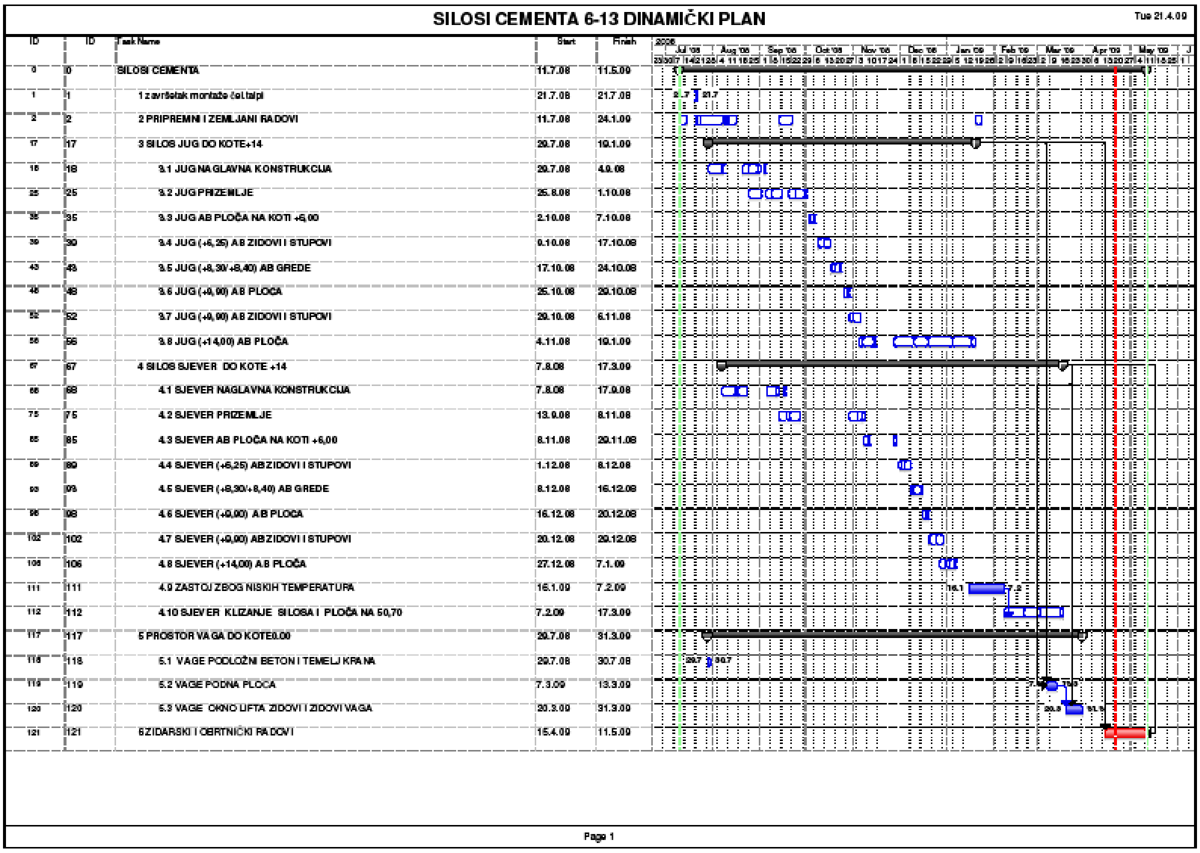

Figure 1: Dynamic Plan

On the basis of detailed financial and operational plans, an analysis of required use of labor and materials was conducted, together with all other necessary resources with the aim of obtaining an economically acceptable offer. Bid had to be in accordance with the approved financial plan of the Investor for realization of the entire project. During the selection and subcontracting of the companies special attention was on skills, expertise and equipment for performing the requested work. Reference to previously delivered objects and client satisfaction with the previous works were requested from subcontractors.

During the planning phase of the project possible risks in construction were defined:

- to ensure continuous performance of works
- to ensure continuous delivery of concrete during the sliding of silo
- to reduce the negative impacts of low temperature.

In order to minimize and control the risks during the planning stage responses to the risk were outlined. In order to ensure continuous performance, contractor had additional equipment and human resources in reserve. Spare concrete factories were provided (from the same manufacturer) with an obligation to be available 24 hours every day during the execution of works, in order to be able to provide the delivery of concrete to the site at any moment. The emergency service was secured with additional equipment in case of accidents or failures. Impact of the weather, impact of the risk which could not be reduced or avoided was the weather conditions. Response to risk was the concrete enhancements for winter casting and monitoring of the weather at the beginning of sliding so that the sliding would start in as favorable weather conditions as possible.

Building the cement silo at the factory Našicecement Inc.

The construction of *Cement Silo No. 6-13* consists of following units (Figure 2):

- system for cement transport and filling the silo chambers
    - air-handling troughs
    - elevators
    - line flows
- system for out-dusting chamber silo and transport of cement for filling and discharging silo
- reinforced cement silo consisting of
    - two times four (4) separated chambers (two batteries) (Figure 3)
    - roof eaves made of the load-bearing steel sections and coverings of trapezium steel sheet
    - supporting cone in the bottom of each chamber
- system for emptying silo and cement transport
    - system for loosening at the bottom of each chamber
    - bolt under each chamber
    - alligator lump under each chamber
    - distribution boxes below each chamber
    - electromotive dosing rollers
    - air-transport beds
    - transportation system of packed cement
- bridge between an exsisting cement silo and elevated tower made of bearing steel sections and coverings of trapezium steel plates (at the height of roof slabs)
- elevated tower made of bearing steel sections and coverings of trapezium steel plates
- area of charging trucks derived from the load-bearing steel sections and coverings of trapezium steel plates,
- area for bulk loading of trucks in four bands with mobile unit for the filling and the corresponding dust control system
- balances
- freight elevator for transport to the silo roof set in elevated tower
- reliable measurement of the cement level in all silo chambers

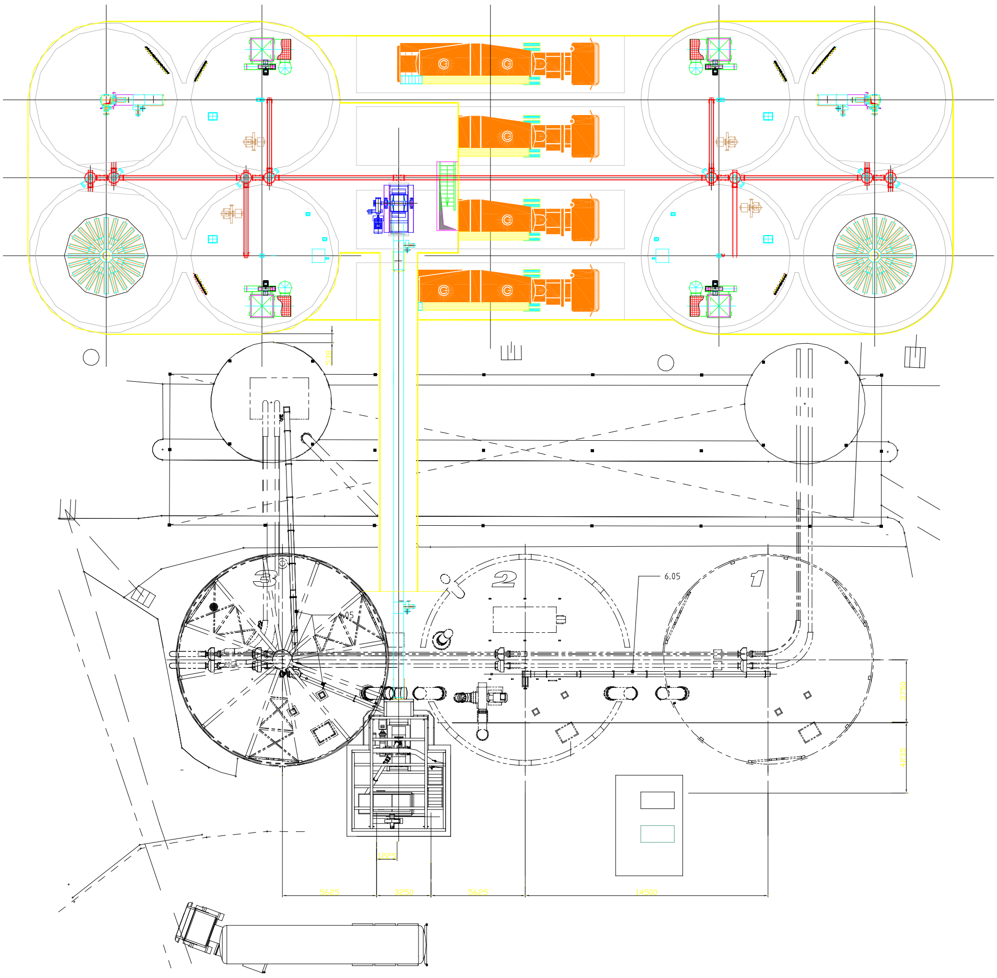

Figure 2: Cement Silo No. 6-13

Figure 3: Chambers of the cement silo

- marking the silo with different types of cement and the loading schedule
- horizontal and vertical signaling of access roads
- system of electrical power supply

- management system of the production process
- software system for loading cement that works in the dosing regime on loading line and workstation for closing the weights and print weight calculations
- software for the dispatching position.

Foundations of the cement silo were done with 93 reinforced concrete pilots with the diameter Ø 150 and Ø 120 cm (Figure 4). On these pilots, reinforced concrete core slabs were constructed with the thickness of 2,00 meters. Bearing structure consists of reinforced concrete columns and walls which are connected by beams and plates. Reinforced-concrete slabs are located on three floors: on 6,00 m, 9,90 and 14,90 m. From the plate, set on level of 14,70 m, sliding for circular chamber silo is continued at the height of 50,70 m. The wall thickness of silo chambers is 25 cm continuously through the entire height of the silo. At the top of the chambers semi-assembled reinforced concrete plate is built leaning on the chamber walls. At the outer-ring beam steel bearings are made for the roof construction.

Figure 4: Reinforced concrete pilots

Construction of monolithic reinforced-concrete structures (up to the level of +14,90 m) required the involvement of 25 workers (carpenters, concrete workers, reinforcement workers and co-workers) with 8-hours working time in three shifts. For the purposes of meeting the deadlines and execution in accordance with the approved dynamic plan during the construction phase, two tower cranes are installed on the building site. DOKA formwork system was used during the construction of monolithic reinforced concrete structure.
The construction to the hight of +14,90 m of the two silos included:

- 4,350 m^3 of concrete
- 690 tons of reinforcement
- 3,900 m^2 of formwork for columns and walls
- 10,350 m^3 of heavy load-bearing scaffolding.

Upon the completion of works on the first silo, up to height of +14.90 m sliding formwork was set and the first battery of silo was constructed. Work on the sliding of silo requested continuous engagement and great discipline of all employees at the building site during 24 hours. The work of employees is organized in two shifts, each 12 hours. In one shift 41 additional workers were hired: 16 bar-benders, 8 concretors, 9 bricklayers, 1 leader, 1 manager, 2 crane operators, 3 engineers (hydraulic pumps), thus the number of employees engaged on the construction site during one day climbed to approximately 150. Work on the sliding at the first battery started on 12th December 2008 and it was finished on 24th December 2009. Work on the sliding at the second battery started on 27th February 2009 and it was finished on 9th March 2009. On both batteries the sliding speed was 2 meters per day.

For vertical transport of concrete and reinforcement to the working platform and into the silo walls tower cranes were used. Concrete was produced in the concrete factory, Nexe Concrete Ltd., Production plant, Našice which is located 8 kilometers from the place of installation. To ensure continuous concrete delivery backup concrete mixing plants in Osijek and Djakovo were provided.

During the execution of works and concrete casting, according to the *Quality performance plan of concrete structures*, constructor continuously carried out quality control of fresh and hardened concrete. Before the installation testing of fresh concrete, namely the consistency of concrete according to the standard HRN EN 12350-2 Testing fresh concrete - Part 2: Slump test was conducted, and the temperature of concrete was measured. Concrete samples were also taken every day for attesting the concrete compressive strength and they matched the class C25/30 of the compressive strength.

CONCLUSIONS

This paper was created in reference to the planning and performance of reinforced concrete works at the cement silo. Project construction was optimally planned out, and plans were realized within a reasonable time-deadline. Good and high-quality organization of human resources and equipment, subcontracting of high-quality and reliable suppliers and contractors ensured the construction of the cement silo in the set conditions so that the construction price, contract terms of performance and proven quality meet the project's set boundaries.

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