Railroad cement warehouse digital system

Y E Vasiliev\textsuperscript{1}, A V Ostroukh\textsuperscript{1}, C B Pronin\textsuperscript{1}, I Y Sarychev\textsuperscript{1}, I.E. Kotlarsky\textsuperscript{1}

\textsuperscript{1} Moscow Automobile and Road State Technical University (MADI), 64, Leningradsky prospect, Moscow, 125319, Russia

E-mail: vashome@yandex.ru, ostroukh@mail.ru

Abstract. In the article the concept of Railroad Cement Warehouse Digital System (RCWDS) with two silos. The article briefly analyzes the ways of unloading hopper, as well as basic equipment for mechanical and pneumatic conveying of cement hopper in the cement silos. The system is a set of hardware maintenance, information, mathematical and software for management of technological objects of railroad warehouse of cement. The system allows you to track trends in cement consumption and accumulation and manage its stocks rationally. The system also allows remote calibration of all silos, further reducing costs and staff time on site. The system is using technological equipment and industrial controllers that allow monitoring silo filling, the occurrence of excess pressure and reduce the risk of dust release into the atmosphere. The system is scalable and can be further modified to control a large number of silos. In accordance with the proposed concept, RCWDS provides the optimum level of automation in the collection and processing of information for generating control signals and transmit them without loss and distortion to the actuators in order to achieve the most efficient warehouse operation cement.

1. Introduction

The current situation in the concrete market is such that cement is often a scarce commodity, and concrete manufacturers prefer to stock large quantities at once to ensure the smooth running of the concrete plant.

In many countries, it is common to transport cement by rail in hopper wagons. In this case, the actual issue is the unloading of cement from under the hopper and its supply to the cement truck. The proximity to the concrete plant of the railway tracks makes it possible to install automatic equipment for receiving cement from railway hopper cars, and at the same time loading the service silos or cement warehouse.

Construction of new and reconstruction of existing long-term storage warehouses and cement terminals with automated control systems [1, 2, 3] is currently an urgent task and is unlikely to cease to be such in the foreseeable future.

2. Materials and Methods

2.1. Methods for unloading cement from hopper cars into storage silos

There are various ways to unload cement from hopper cars, each with their own advantages and disadvantages.
2.1.1. **Unloading hopper wagons using sliding auger conveyors**

This is a mechanical method, which involves the mechanical extraction of cement from under the car using an auger, and its subsequent transportation to silos, also by a vertical screw conveyor (Fig. 1).

The horizontal auger fits into the space between the sleepers. To do this, it is necessary to place there a protective box with a section of 400-450 mm, in which the screw feeder is laid. The unloading of cement into the inlet of the auger is carried out through a magnetic grate, which catches metal inclusions present in the transported cement, and extension boards, the upper frame of which is attracted to the neck of the car, thereby ensuring minimal spreading of cement. The auger feeder feeds material into a vertical auger conveyor which transports the material to one of two silos. The choice of the silo for loading is carried out by means of the overhead mechanism.

If necessary, the auger feeder and conveyor can be dismantled and transported to another site.

This technical solution does not allow for high performance of unloading bulk material, because the height of the space between the neck of the car and the rolling auger is minimal. But with the correct location of the system, it does not require coordination of its placement and minimizes construction work. This unloading system also has restrictions on material intake, which means that not all hopper car models can be efficiently unloaded. If you use high-quality components, then the advantages of this system include low maintenance costs, and, as a result, a quick return on investment.

2.1.2. **Unloading hopper wagons using a pit**

Using the under-rail space for unloading the car (Fig. 2), can provide high productivity of the process, use various models of hoppers, and makes it possible to place pneumatic chamber pumps in the pit for pumping material into service silos.
This option is convenient if the pit already exists and there is project documentation approved by JSC Russian Railways (JSC Russian Railways), otherwise it will take considerable time and money to agree on the project. In addition, in many regions there are difficulties with the level of groundwater, which makes it impossible to build a full-fledged pit.

At the location of the car, a shelter from wind and precipitation is being constructed, which makes it possible to effectively use the dedusting system of the unloading process. To prevent spreading of material under the car along the railway tracks, the equipment set includes easily mounted, front boards.

To ensure the normal operation of the equipment in the pit, the package includes electric heaters, which automatically maintain the required temperature. Taking into account that the temperature in the pit rises during operation of the equipment, the heaters are started before starting work, or in between short stops.

2.1.3. Unloading of hopper cars with partial use of the under-rail space.

With this option, transportation from under the car is carried out mechanically, as an option - by a screw feeder (Fig. 3).
The performance of such an arrangement may be less than the option with a pit, because the space between the neck of the car and the receiving auger is not large, so the productivity will depend on the material flow and the operation of the auger. In addition, this unloading technology is not suitable for every hopper model, because the unloading throat of the car is significantly larger than the intake throat of the auger, which will not allow efficient unloading of material. Therefore, it is very important to know what type of carriages will be supplied with material.

A significant advantage of this option is the shallow depth of the auger, which makes it possible to place the system in areas where there is high groundwater. This option greatly facilitates the coordination of the project with Russian Railways, but does not exclude it.

2.2. Automation object
The object of automation is a railroad terminal for transshipment of cement from hopper cars to cement trucks (Fig. 4) [4, 5].
From an economic point of view, the organization of a cement warehouse on the basis of several large-volume cement silos (for example, 300 or 500 tons) is optimal.

The main requirements for its functionality of a cement terminal are:

- time for unloading one wagon less than one hour (including wagon cleaning);
- minimization of energy consumption during cement transportation;
- prevention of over-grading of cement;
- reduction of dusting in the area of unloading wagons;
- prevention of its caking during long-term storage;
- measurement of the current level of cement;
- controlled shipment of cement to the consumer;
- reliability of the terminal equipment.

It is proposed to use this method of unloading hopper cars for the automated control system for technological processes of the railroad cement warehouse. The system consists of a receiving hopper located in a pit under the railway tracks, where cement is unloaded from hopper cars, a screw conveyor, through which cement from the receiving hopper enters a pneumatic chamber pump, from which, under the pressure of compressed air, cement is fed through pipes to silos (see. fig. 4).

The implementation of the automation project is carried out in stages. At the first stage, a system is automated, which consists of a receiving device and two silos for handling cement. At the next stages, it is possible to increase the number of silos by a multiple of two (4, 6, 8, etc.).

2.3. Pneumatic chamber pumps

Considering the real quality of the cement supplied for transshipment and the non-guaranteed "cleanliness" of the wagons used for its transportation, along with the requirement for the warehouse equipment to operate with maximum reliability, it was decided to use pneumatic chamber pumps as cement transportation.

The pneumatic chamber pump is designed for pneumatic transportation of bulk materials with a fraction of not more than 2 mm. The product is transported in a cyclic mode by means of compressed air from an external compressor, at a pressure of no more than 6 bar. Pneumatic chamber pumps are successfully used for unloading cement from railway hopper cars with further supply to storage silos.

According to their design, the following types of pneumatic chamber pumps are distinguished:

- pneumatic chamber pumps with manual control;
- pneumatic chamber pumps with an automatic control system;
- pneumatic chamber pumps with an automatic control system and a shut-off valve from pneumatic transport.

A manually operated pneumatic chamber pump is optimal for minor and / or intermittent product handling operations. Depending on the volume, they can be used, for example, as part of a big bag unloading station or as part of an aspiration unit and providing the collected dust 1-3 times a day.

Pneumatic chamber pumps with an automatic control system ensure efficient operation at short and medium distances - up to 80 m. It is possible to feed material at a distance of up to 500 m with a significant loss of productivity.

The disadvantages of these models of pumps from some manufacturers is the irrational air flow rate at long delivery distances and the inability to combine a group of pumps into one pneumatic transport line. The unloading of the hopper car with the supply of cement to the silos can be done with only one pump, which significantly increases the unloading time.

Pneumatic chamber pumps with an automatic control system and a shut-off valve from pneumatic transport are currently the most modern mechanisms for pneumatic conveying and can be used at significant feed distances (over 500 m). These pumps work perfectly in pneumatic conveying systems not only in single mode, but also in pair mode (Fig. 5), which increases productivity by 1.5-2 times.
Figure 5. Twin pneumatic chamber pumps with automatic control system and shut-off valve

Unloading of the hopper car can be carried out by two pumps with cement supply through one pneumatic transport line to the group of silos.

To achieve the maximum energy efficiency of the cement pumping process, high-tech pneumatic chamber pumps with an automatic control system and a shut-off valve were selected, which provide flexible control of the technological process at each phase.

3. Results and Discussions
The RCWDS of the cement warehouse is designed to control the control of the equipment of cement warehouses of various volumes and with a receiving device for unloading hopper cars in automatic, semi-automatic and manual remote modes of operation. An example of a mnemonic diagram of an operator station, developed using a modern SCADA system, is shown in Figure 6 [6, 7].
The typical technological equipment of the cement warehouse includes:

- sensors of filling level of storage tanks and bunkers-consumers (threshold and tracking);
- filters for cleaning outgoing air with an automatic cleaning system;
- controlled switches of cement flow;
- pneumatic chamber pumps (see Fig. 5) complete with valves, gates, pressure and level sensors;
- fans and filters of the intake system aspiration;
- auxiliary pressure gauges for monitoring air pressure in the control and pumping pneumatic networks;
- consoles for loading consumer bunkers.

The RCWDS of the cement warehouse performs the following functions:

- constant monitoring of the filling levels of the storage tanks (Fig. 7) and consumer bins;
- automatic execution of cement pumping processes.
Figure 7. Cabinet for automation, control and indication of cement levels in silos

This provides:

- selection of sources and receivers as directed by the operator or automatically, taking into account the cement grades and filling levels;
- installation of mechanisms for switching the flow to the required positions (route preparation) with the inclusion of pre-start alarm bells;
- starting the operation of pumps in a cyclic mode and monitoring their operation until the end of pumping;
- monitoring the state of the line and all necessary conditions during pumping, automatic shutdown of the process and issuing messages to the operator in case of deviations;
- termination of the pumping process at the command of the operator, or upon filling the receiver tank, or emptying the source tank;
- purging of the used sections of the route to release material;
- recording of the pumping operations (work log) with fixing the time, cement grade and filling levels at the beginning and at the end of pumping.

The system provides:

- possibility of simultaneous synchronous operation of several pumps on one outlet line to increase productivity;
- simultaneous independent execution of several pumping processes on non-intersecting sections of the route.

4. Conclusion

By combining an efficient way of unloading hopper cars, high-tech pneumatic chamber pumps, modern technological solutions, effective and fully functional automation systems, it is possible to achieve high efficiency of cement handling processes, good timing and high reliable operation of the entire technological complex on the types of cement existing in the region.

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References
[1] Jing S and Meng Q 2009 Research and design of remote real-time supervisory system based on OPC in cement enterprise IEEE International Conference on Automation and Logistics, 761-765 doi: 10.1109/ICAL.2009.5262822
[2] Ostroukh A V, Nedoseko I V, Surkova N E and Bulatov B G 2016 Automated Control System for the Milling Unit of Mineral Powders Plant International Journal of Applied Engineering Research 11(4) 2625-2628
[3] Ostroukh A, Maksimychev O, Nikolaev A, Kolbasin A and Nedoseko I 2016 Development of automation of the drying and milling unit for the mineral powders plant ARPN Journal of Engineering and Applied Sciences 11(9) 5717-5721
[4] Hettiarachchi B D, Dilum Bandara H M N and Samarasekera N A 2018 Automated Multi-Plant Scheduling of Ready-Mixed Concrete Trucks IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI) (Singapore) pp 43-48 doi: 10.1109/SOLI.2018.8476729
[5] Syahputra R H, Komarudin K and Destyanto A R 2018 Optimization Model of Ready-Mix Concrete Delivery Route and Schedule: A Case in Indonesia RMC Industry 3rd International Conference on Computational Intelligence and Applications (ICCIA) (Hong Kong) pp 21-25 doi: 10.1109/ICCIA.2018.00012
[6] Teixeira M A, Salman T, Zolanvari M, Jain R, Meskin N, Samaka M. 2018 SCADA System Testbed for Cybersecurity Research Using Machine Learning Approach Future Internet 10(8):76 https://doi.org/10.3390/fi10080076
[7] Aghenta L O and Iqbal M T 2019 Development of an IoT Based Open Source SCADA System for PV System Monitoring IEEE Canadian Conference of Electrical and Computer Engineering (CCECE) (Edmonton, AB, Canada, 2019) pp 1-4 doi: 10.1109/CCECE.2019.8861827