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Development of an energy-saving design for the feeding system of a concrete mixing plant

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The study focuses on the development of an energy-saving design for concrete mixer mix components supply system to enhance efficiency and reduce environmental impact. The proposed changes to the schematic diagram include the implementation of separate hoppers with individual conveyors to optimize energy consumption and increase productivity. These modifications aim to improve energy efficiency, reduce material change time, and prevent congestion in the supply system, ultimately leading to enhanced productivity and streamlined production processes. This study highlights the importance of innovative design solutions in the feeding supply system of industrial plants to drive sustainability and efficiency improvements.

Keywords: concrete mixing plant, concrete mixer mix components supply system, energy efficiency, ecology, productivity, material change time, sustainability, concrete

Розробка енергозберігаючої конструкції системи живлення бетонозмішувальної установки

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Виробництво бетону є важливою складовою будівельної промисловості, проте воно відоме своїми великими енергетичними витратами та негативним впливом на довкілля. У зв'язку з цим, дослідження системи живлення бетонозмішувальної установки має велике значення для підвищення сталості та зменшення впливу на навколишнє середовище. В статті проводяться дослідження, які спрямовані на оптимізацію виробничих процесів та зменшення споживання енергії в бетонозмішувальних установках. У роботі використовувалися моделювання та аналіз технічних параметрів конструкції бетонозмішувальної установки. Однією з ключових проблем, що виявлені, є неефективність системи живлення, що призводить до зайвого споживання енергії та втрат продуктивності. З метою вирішення цієї проблеми, запропоновано змінити принципову схему системи живлення, розташовуючи кожен бункер окремо із власним конвеєром. Результати дослідження показали, що запропоновані зміни сприяють підвищенню енергоефективності установки за рахунок мінімізації енерговитрат, підвищення ефективності процесу та зменшення ризику перешкод. Такі покращення можуть значно зменшити витрати енергії та покращити загальну продуктивність бетонозмішувальної установки. Висновки дослідження вказують на важливість постійного пошуку нових технологій та методів для зменшення енергоспоживання та покращення сталості виробництва. Запропоновані зміни можуть стати важливим кроком у напрямку створення екологічно чистих та енергоефективних установок для виробництва бетону, що відповідає сучасним вимогам сталого розвитку.

Ключові слова: бетонозмішувальний завод, система живлення, енергоефективність, екологія, продуктивність, час зміни матеріалу, стійкість, бетон

Introduction.

Nowadays, with the constant growth of the global construction sector and the tightening of environmental requirements, the development of energy-saving technologies is becoming an extremely urgent and important task. One of the key areas of improvement is the feeding systems of concrete mixing plants, which play an important role in the production of concrete for construction.

Concrete mixture is widely used in construction in the manufacture of various monolithic and prefabricated structures. This material is a homogeneous mass consisting of a viscous substance (cement), coarse and fine-grained fillers (crushed stone, sand), water, as well as various additives that improve the properties of concrete. In each case, a careful calculation of the components is carried out, which must be observed when compiling the proportions [1].

The production process of concrete and mortar mixtures is a series of sequential mechanized and, mainly, automated operations: warehousing and storage of inert materials and cement; dosage of sand, gravel, water, chemical additives and pigments; mixing components; and transporting concrete to its destination [2].

The ever-increasing requirements for concrete quality and production efficiency, along with the need to reduce energy consumption and emissions of harmful substances into the air, require revolutionary changes in this area. Therefore, the purpose of this scientific study is to develop a new energy-saving design of the feeding supply system for concrete mixing plants, aimed at improving their efficiency and reducing the negative impact on the environment.

Review of the research sources and publications.

In recent times, a significant amount of research has been conducted in the field of concrete mixing plants and plants aimed at improving the quality and efficiency of concrete production. These researches include the development of new technologies, improvements in the processes of mixing and transporting concrete, as well as improvements in the designs of the equipment itself. However, among the large amount of researches, relatively little attention has been paid to the feeding supply system of the concrete mixing plant, which plays a key role in ensuring stable and effective mixing of concrete components.

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Recent research on energy-efficient designs for concrete mixing plant feeding systems describes the use of modern, high-efficiency motors and control systems that optimize the operation of concrete mixing plants with minimal energy consumption [4].

A review of publications of modern methods and technologies aimed at improving energy efficiency in concrete mixing plants was carried out, in which various aspects were studied, such as the use of renewable energy sources, optimization of technological processes and the introduction of energy-saving technologies [6].

Studies have also shown the possibility of using innovative methods for optimizing processes, automating and improving the efficiency of concrete mixing plants [9].

Definition of unsolved aspects of the problem

Although there are works investigating the integration of renewable energies into concrete mixing plants [7], and more detailed research is needed to identify rational ways to use them and to address the technical and economic challenges of this process.

Detailed study of different technological processes impact on concrete mixing plants energy efficiency, as well as determining the rational parameters of these processes are very important to ensure efficient use of energy.

It is necessary to develop and implement the latest materials and technologies to improve the energy efficiency of concrete mixing plants, such as energy-saving drives and automation systems.

Problem statement

The purpose of this study is to conduct a comprehensive analysis of concrete mixing plants design in order to identify and solve unresolved problems that affect the energy efficiency of these plants, as a result of which to design feeding system, including the use of the latest technologies.

Basic material and results

The technological process of production of concrete mixtures and mortars at the modern level is a chain of interconnected mechanized and, in most cases, automated operations: warehouse processing of materials, including loading and unloading and stacking operations; transportation of components to the supply bins of the mixing unit; dosage of components; preparation (mixing) of the mixture; unloading of the finished mixture [11].

With the dismembered production technology, the dosed components are mixed on the road transport or in mixing plants located in the places of concrete laying.

Depending on the purpose, capacity and characteristics of consumer facilities, there are stationary and quickly relocated concrete plants, quickly relocated prefabricated plants and mobile mixing plants.

Stationary plants of continuous operation, produce ready-mixed concrete (mortar) for various consumers or for the plant of reinforced concrete prefabricated structures.

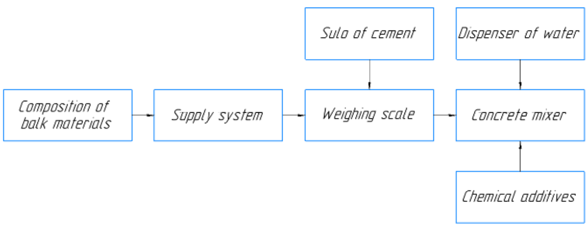

Figure 1 – Schematic diagram of a concrete mixing plant

Quickly relocated plants are built for the construction of specific facilities, taking into account their operation for several years. For better use, such plants should be able to quickly relocate to other facilities without high costs for plant and dismantling of equipment and stationary structures.

Mobile concrete and mortar mixing plants are units mounted on trailers or consisting of blocks transported by vehicles. These plants are designed to serve concentrated objects.

The plant or plant includes: aggregate and cement warehouses with stacking machines and lifting and conveying equipment to feed them to the mixing department; mixing compartment with dosing equipment, consumable hoppers, mixing machines and devices for receiving the finished mixture and dispensing it to the consumer.

Concrete mixing and mortar mixing shops and plants are classified according to the following criteria: mode of operation - batch and continuous action; layout scheme - for high-rise and stepped. With the high-altitude scheme, the components are raised to their full height once, after which they move only under the influence of gravity during the entire technological cycle.

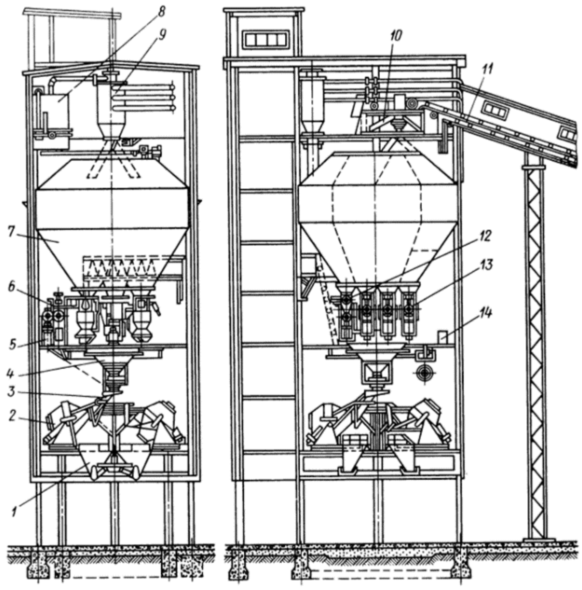

Figure 2 – Diagram of a concrete mixing unit with four concrete mixing units

With a two-stage layout scheme, the concrete mixture is sequentially lifted first into the consumable hoppers, then, after dosing, into the mixing machine.

Figure 2 shows a concrete mixing unit with four gravity concrete mixers, arranged in an elevation scheme [10]. The volume of the finished batch of each concrete mixer is 1600 liters.

Aggregates are fed from the warehouses by a conveyor belt 11 through a rotary funnel 10 to the compartments of the feed bins. Cement is fed by pneumatic transport to cyclone 8, from which it is sent through an air chute to hopper 7. The final air purification is carried out in the bag filter 9. From the consumable hoppers, the cement is poured through the batcher 12 and the aggregates through the batcher 13 into the collecting hopper 4 with a rotary funnel into the concrete mixer 2. Water through the dispenser 6 and liquid additives through the dispenser 5 flow directly into the rotary funnel through the pipeline.

The finished mixture from the concrete mixers is discharged into the dispensing hoppers 1. The operation of the equipment is controlled from the console 14, located in the dispenser compartment.

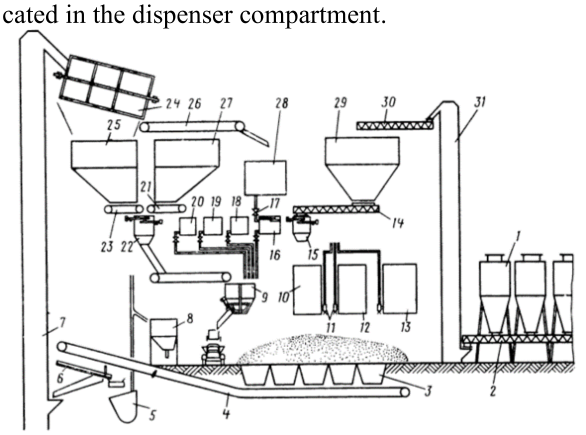

Figure 3 – Technological diagram of a concrete mixing unit with a turbulent mixer

Tower-type concrete mixing units with a layout similar to those of the concrete batching plant in question. Figure 3 shows the technological scheme for the preparation of mortar and concrete on an automated structural unit in which turbulent mixers are used. Cement from silos 1 by screw 2, elevator 31 and screw 30 is fed to hopper 29. From the hopper, the cement is fed by the feeder 14 to the batcher 15, from which it enters the mixer 9. Aggregates from warehouses 3 are fed by conveyor 4 to screen 6. The sifted sand is fed by the elevator 7 into the drum sand grinder 24 and then into the hopper 25. Large inclusions from the screen 6 are fed by the shaft hoist 5 into the waste bin 8. Crushed stone from the warehouse is transported by the same chain of machines and transport 26 to hopper 27 From the hoppers, the sand is fed by feeders 21 and 23 to the batcher 22 and further to the mixer. Water is supplied to the mixer from the tank 28 through the valve 17 and the dispenser 16. Lime from tank 13 and additives from tanks 12 and 10 are fed by pumps 11 to the corresponding dispensers 18, 19 and 20, from which they are drained into the mixer.

Figure 4 shows a diagram of a two-stage continuous concrete plant (SB-75 type), with a capacity of 30 m^3/h, designed for the preparation of concrete in open areas during the construction of roads, airfields, etc.

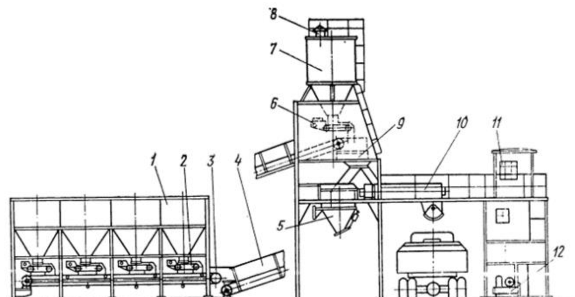

Figure 4 – Schematic diagram of a continuous concrete plant

The plant consists of three main units: a batching unit for aggregates, a mixing department with a cement hopper and a control unit. Aggregates from hoppers 1 are fed through continuous dispensers 2 through the conveyor 3 to the inclined conveyor 4 and the collecting hopper 9. Cement from cement trucks is sent to the hopper 7, equipped with a filter 8, and then to the collecting funnel with a batcher 6. The plant can produce the finished mixture by a continuous mixer 10, where water is supplied by a dosing pump 12 from a tank located under the control unit 11, or to ship separately dosed dry components and water to concrete mixer trucks. The unit has a cyclic calibration dispenser 5, mounted on a sliding frame.

The dosing unit of a plant or plant is one of the main units, it can be called a bulk material feeding system [14]. It consists of hoppers for temporary storage of material, dispensers and belt conveyors.

Hoppers for bulk materials belong to the main type of auxiliary equipment. The purpose of the hopper is to create an operational stock of materials for the smooth operation of production [15].

Consumable hoppers are designed so that they can contain the materials necessary for the preparation of the concrete mixture for 2-4 hours of operation. Usually, the stock of materials in consumable bins is taken to be equal: for aggregates - for 1-2 hours, for cement - 2-3 hours. The number of hoppers or its compartments is assigned to the development of the technological scheme of production and depends on the nomenclature of mixtures, the productivity of the line, the choice of the layout of the plant (one-, two-stage, and others). Usually their number is at least two for each type of material. The consumable hoppers are located above the dispensers and are equipped with gates at the outlets.

The design properties of concrete mixtures and concretes are ensured by dosing (measuring) their components with the required accuracy. This operation takes place with the help of dispensers. Dispensers can be volumetric and weight, batch and continuous, with manual, semi-automatic and automatic control. In modern conditions, automatic batch dispensers are used in most cases.

A batch weighing or volumetric weighing batch dispenser consists of a measuring device (a rectangular or more often cylindrical vessel with a pyramidal or conical lower part), a shutter and a weighing mechanism (device). Until recently, concrete mixing plants used weighers with a lever weighing mechanism, which was unreliable, quite complex and difficult to automate. Recently, weighers on load cells have been widely used, the design of which is very simple: the gauge is installed on load cells or suspended from load cells. The most commonly used strain gauges are resistance that varies depending on the deformations caused by gravity. The electrical signal is processed by the controller.

The use of strain gauges has made it possible to sequentially dose several materials with a single batcher, e.g. fine and coarse aggregates, different fractions of coarse aggregate, as they provide the required accuracy within the weighing range. In addition, it is possible to carry out weight dosing of bulk materials with the help of weighing conveyors-dosers.

The last component of the system is the belt conveyor, which feeds the metered material to the mixer.

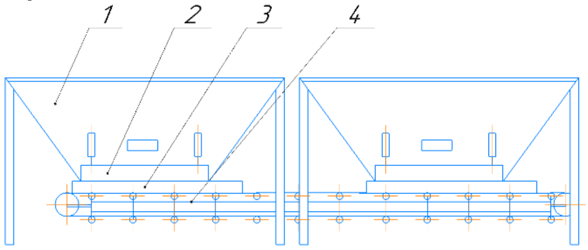

Figure 5 – Feeding supply system of the concrete mixing plant:
1 – receiving hopper; 2 – pneumatic shutter;
3 – measuring device; 4 – conveyor.

The feeding system consists of a belt conveyor, which is attached to the hoppers using load cells and is a weighing platform. Between the conveyor and the hoppers, there are meters for sand and gravel, the volume of which is equal to the required portion for one batch of concrete. The material is loaded into hoppers, then this material is dosed to prepare concrete. The operator gives a command and the hopper gates open one by one, through the pneumatic drive, the material enters the gauge and when the set weight is reached, the gate closes. The gauge and shutter are quite oversized elements, this is done in order to reduce the hanging of materials in the hopper and speed up dosing. Then the conveyor turns on and transports the material to the mixer. The conveyor drive must be powerful, since the gauges contain material for one batch. For example, if the mixer has a working volume of 0.5 m^3, then the mass of bulk materials will be about 1000 kg. The conveyor will turn off when there is no material left in the gauges and on the belt. The disadvantages of this equipment are a large shutter, which significantly affects the error during weighing the material, a powerful and energy-consuming conveyor, vibration occurs during the operation of the equipment, which negatively affects the load cells and creates a large error in weighing and premature failure, as well as the need to free the conveyor belt from materials, which significantly affects the performance of the plant.

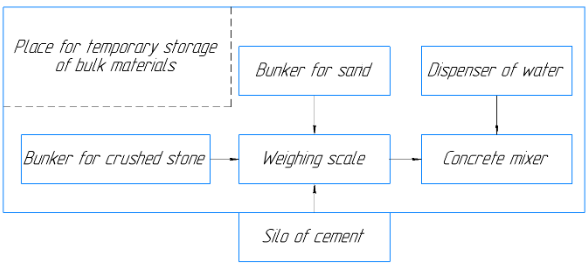

Figure 6 – Schematic diagram of a concrete mixing plant

It is proposed to change the design and schematic diagram of the feed system so that each hopper is located separately from each other and has its own conveyor. Weighing will take place in a separate gauge, which is mounted on load cells or a weighing platform. The hopper of the feeder will be a gauge in which there are no gates, and a gate is installed in the discharge hole to regulate the supply of materials.

As a conclusion, the proposed system will have a number of advantages over the existing one.

During operation, vibration will not affect the weighing system, as it is located separately from the working units. There are no gates and gauges in the feeders, which greatly simplifies the design and reduces the loading height of the material with the same volume of hoppers. Although there will be several conveyors, they will be smaller and not as powerful. It will be possible, if necessary, to add material in any sequence and quantity, and there will always be material on the belt, which will allow instant dosing and significantly increase the productivity of the unit. With this layout, the system will be more compact, and when organizing a canopy to protect against precipitation, there will be a place for temporary storage of materials. Equally important is the fact that cement can be dosed using a single weighing system.

Conclusions

The results of the study of the energy efficiency of the concrete mixing plant design led to an important conclusion regarding the need for changes in the schematic diagram of the feeding supply system. The proposed changes provide for the location of each hopper separately from each other, each of which will have its own conveyor.

This new feeding system schematic diagram will help improve the energy efficiency of the plant in several ways. The isolated arrangement of hoppers and the use of separate conveyors will optimize the operation of the feeding system, avoid unnecessary energy consumption for transporting materials. Each hopper will be able to operate independently, which will help increase productivity and reduce the time to change the material being loaded.

The introduction of separate conveyors for each hopper will reduce the risk of congestion and interference in the feeding system, which will help to avoid wasting time and energy on solving such problems.

Therefore, the proposed changes in the design and schematic diagram of the feed system of the concrete mixing plant have significant potential to improve energy efficiency and optimize production processes. Their implementation can be an important step towards the creation of environmentally friendly and change-resistant concrete production plants.

References

1. Назаренко І.І., Туманська О.В. (2004). Машини і устаткування підприємств будівельних матеріалів: конструкції та основи експлуатації: Підручник.- К.: Вища шк., с. 590.

2. Сівко В.Й., Поляченко В.А. (2004). Обладнання підприємств промисловості будівельних матеріалів і виробів: Підручник. – К.: ТОВ «АВЕГА», с. 280.

3. Савенко В.Я., Словінська О.С., Каськів В.І., Петрович В.В. (2001). Проектування асфальтобетонних та цементобетонних заводів для потреб дорожнього будівництва. Посібник. Київ, 218 с.

4. Валовой О.І., Валовой М.О., Єрьоменко О.Ю. (2014). Нове обладнання і технології для виготовлення, транспортування і подачі бетону. Гірничий вісник, 97, 125-129.

5. Шпатакова О.Л (2019). Дослідження негативного впливу будівельного підприємства на навколишнє природне середовище. Економіка та управління підприємствами, 30 (69), 85-90 https://doi.org/10.32838/2523-4803/69-5-43

6. Шульгін Ю. В., Жнітов Я. В. (2015). Дослідження можливостей енергозбереження у технології виробництва залізобетону. Енергетичні та теплотехнічні процеси й устаткування. Вісник НТУ «ХПІ», 16 (1125), 157-161

7. Назукін Ю.М. (2013). Стан та перспективи розвитку підприємств з виробництва будівельних матеріалів. Науково-практичне видання «Незалежний аудитор», 5 (10), с. 59-63

8. Moonseo Park, Woo-Young Kim, Hyun-Soo Lee, Sangwon Han (2011). Supply chain management model for ready mixed concrete. Cutomation in Construction, 1 (20), Pages 44-55 https://doi.org/10.1016/j.autcon.2010.07.005

9. V. Deligiannis, S. Manesis (2008). Concrete batching and mixing plants: A new modeling and control approach

1. Nazarenko I.I., Tumanska O.V. (2004). Machines and equipment of building materials enterprises: designs and basics of operation: Textbook. - K.: Vyshcha shk., p. 590.

2. Sivko V.Y., Polyachenko V.A. (2004). Equipment of construction materials and products industry enterprises: Textbook. - K.: "AVEGA" LLC, p. 280.

3. Savenko V.Ya., Slovinska O.S., Kaskiv V.I., Petrovych V.V. (2001). Design of asphalt concrete and cement concrete plants for the needs of road construction. Manual. Kyiv, 218 p.

4. Valovoi O.I., Valovoi M.O., Eremenko O.Yu. (2014). New equipment and technologies for manufacturing, transporting and supplying concrete. Mining Bulletin, 97, 125-129.

5. Shpatakova O. L. (2019). Study of the negative impact of the construction enterprise on the natural environment. Economics and Enterprise Management, 30 (69), 85-90 https://doi.org/10.32838/2523-4803/69-5-43

6. Shulgin Yu. V., Zhnitov Ya. V. (2015). Study of energy saving possibilities in reinforced concrete production technology. Energy and heat engineering processes and equipment. Bulletin of NTU "KhPI", 16 (1125), 157-161

7. Nazukin Yu.M. (2013). The state and prospects of the development of construction materials production enterprises. Scientific and practical publication "Independent Auditor", 5 (10), p. 59-63

8. Moonseo Park, Woo-Young Kim, Hyun-Soo Lee, Sangwon Han (2011). Supply chain management model for ready mixed concrete. Cutomation in Construction, 1 (20), Pages 44-55 https://doi.org/10.1016/j.autcon.2010.07.005

9. V. Deligiannis, S. Manesis (2008). Concrete batching and mixing plants: A new modeling and control approach

based on global automata. Automation in Construction, 4 (17), 368-376
https://doi.org/10.1016/j.autcon.2007.06.001

10. Zhenyuan Liu, Yakun Zhang, Minghui Yu, Xiaolu Zhou (2017). Heuristic algorithm for ready-mixed concrete plant scheduling with multiple mixers. Automation in Construction, 84, 1-13
https://doi.org/10.1016/j.autcon.2017.08.013

11. Shangyao Yan, Weishen Lai, Maonan Chen (2008). Production scheduling and truck dispatching of ready mixed concrete. Transportation Research Part E: Logistics and Transportation Review, 1 (44), 164-179
https://doi.org/10.1016/j.tre.2006.05.001

12. Remon Fayek Aziz (2018). Statistical model for predicting and improving ready mixed concrete batch plants' performance ratio under different influences. Alexandria Engineering Journal, 3 (57), 1797-1809
https://doi.org/10.1016/j.aej.2017.06.016

13. Tian, X., Mohamed, Y., Abourizk, S. (2010). Simulation-based aggregate planning of batch plant operations. Canadian Journal of Civil Engineering, 10 (37), 1277-1288
DOI: 10.1139/L10-071

14. Тодавчич В. І.(2018). Чинники, що впливають на якість дозування. Наукові розробки молоді на сучасному етапі : тези доповідей XVII Всеукраїнської наукової конференції молодих вчених та студентів, Київ : КНУТД, с. 447-448.

15. Семенцов В. В. (2019). Теоретичне дослідження руху сипких матеріалів в бункерах. Вісник Харківського національного технічного університету сільського господарства, 205, с. 249-256.

16. Семенцов В. В. (2018). Розробка нових енергозберігаючих конструкцій дозаторів сипких матеріалів. Вісник Харківського національного технічного університету сільського господарства, 192, с. 227-233.

17. Ничеглод В. В., Бурмістенков О. П., Стаценко В. В. (2022). Дослідження впливу форми бункера на характер протікання порошкових сипких матеріалів. Технології та інжиніринг, 6(11), 42-51
https://doi.org/10.30857/2786-5371.2022.6.4

18. Лизан Х.О., Верескля Д.В., Федорів П.С. (2017). Дослідження Оптимальних Параметрів Бункерного Живильника. Матеріали VI Міжнародної науково-технічної конференції молодих учених та студентів, 204

based on global automata. Automation in Construction, 4 (17), 368-376
https://doi.org/10.1016/j.autcon.2007.06.001

10. Zhenyuan Liu, Yakun Zhang, Minghui Yu, Xiaolu Zhou (2017). Heuristic algorithm for ready-mixed concrete plant scheduling with multiple mixers. Automation in Construction, 84, 1-13
https://doi.org/10.1016/j.autcon.2017.08.013

11. István Kocserha, Ferenc Kristály (2010). Effects of Extruder Head's Geometry on the Properties of Extruded Ceramic Products. Materials Science Forum, Vol. 659, 499-504
doi:10.4028/www.scientific.net/MSF.659.499

12. Remon Fayek Aziz (2018). Statistical model for predicting and improving ready mixed concrete batch plants' performance ratio under different influences. Alexandria Engineering Journal, 3 (57), 1797-1809
https://doi.org/10.1016/j.aej.2017.06.016

13. Tian, X., Mohamed, Y., Abourizk, S. (2010). Simulation-based aggregate planning of batch plant operations. Canadian Journal of Civil Engineering, 10 (37), 1277-1288
DOI: 10.1139/L10-071

14. Todavchych V. I. (2018). Factors affecting the quality of dosing. Scientific developments of youth at the current stage: abstracts of reports of the XVII All-Ukrainian scientific conference of young scientists and students, Kyiv: KNUTD, p. 447-448.

15. Sementsov V. V. (2019). Theoretical study of the movement of loose materials in bunkers. Bulletin of Kharkiv National Technical University of Agriculture, 205, c. 249-256.

16. Sementsov V. V. (2018). Development of new energy-saving constructions of bulk materials dispensers. Bulletin of Kharkiv National Technical University of Agriculture, 192, p. 227-233.

17. Nycheglod V.V., Burmistenkov O.P., Statsenko V.V. (2022). Study of the influence of the shape of the hopper on the nature of the flow of powdery loose materials. Technologies and Engineering, 6(11), 42-51
https://doi.org/10.30857/2786-5371.2022.6.4

18. Lyzan H.O., Veresklya D.V., Fedoriv P.S. (2017). Study of the Optimal Parameters of the Bunker Feeder. Materials of the VI International Scientific and Technical Conference of Young Scientists and Students, 204