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STRENGTHENING THE FOUNDATIONS OF THE PRIMARY AMMONIA REFORMING FURNACE IN CONDITIONS WITHOUT WORKING FREE SPACE USING SELF-COMPACTING CONCRETE

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Анотація

Ця наукова робота присвячена важливому питанню з розробки технологічних рекомендацій по виконанню робіт з підсилення фундаментів споруд хімічної промисловості, які виконуються у стиснених умовах. На прикладі проекту підсилення фундаментів печі первинного риформінгу аміаку Одеського припортового заводу обґрунтовано не доцільність використання звичайних важких бетонів через відсутність можливості ефективного вібрування суміші під дном печі. Запропоновано використання самоущільнюючого бетону для мінімізації відсотка людської праці. Описано методологію підбору добавок в бетон, включаючи суперпластифікатори, для створення бетонної суміші з високою рухливістю та малим водоцементним відношенням. Доведено перевагу запропонованого методу підсилення над класичними, з використанням вартісного роботизованого оснащення.

Ключові слова: підсилення, самоущільнюючий бетон, монолітна плита, суперпластифікатори, полікарбоксилати, мікрокремнезем, добавки.

Abstract

This scientific work is devoted to the important issue of the development of technological recommendations for the performance of works on strengthening the foundations of chemical industry structures, which are performed in compressed conditions. Using the example of the project to strengthen the foundations of the ammonia primary reforming furnace of the Odesa Port Plant, have been substantiated the inexpediency of using ordinary heavy concrete due to the lack of the possibility of effective vibration of the mixture under the bottom of the furnace. Have been offered the use of self-compacting concrete to minimize the percentage of human labor. Have been described the methodology for the selection of concrete additives, including superplasticizers, to create a concrete mixture with high mobility and a low water-cement ratio. Have been proven the superiority of the proposed method of amplification over classical methods using expensive robotic equipment.

Key words: reinforcement, self-compacting concrete, monolithic slab, superplasticizers, polycarboxylates, microsilica, additives.

Introduction

The industrial development of the chemical industry of China and Ukraine is a key factor in the economic growth of these countries and the whole world. China in the Asian region and Ukraine in Europe are recognized leaders in chemical production. However, both countries have similar problems with energy resources. China's industry due to overpopulation and active dynamics of development and Ukrainian industry due to a long economic crisis and military actions. Therefore, most enterprises of the chemical industry are in conditions of energy "starvation" [1]. For both countries, the problem of greenhouse gases is important and relevant, therefore measures aimed at reducing such emissions and saving material resources are important and relevant. In connection with the significant wear and tear of the material fund of chemical industry enterprises, an important and urgent task has arisen to develop rational methods of strengthening worn-out building structures now [2].

A typical enterprise that suffers from a lack of energy resources is the Odesa Port Plant, located in the Yuzhne city, Odesa region [1, 2]. Since the production facilities of the plant are built near the Black Sea, the engineering and geological conditions of the enterprise site, in comparison with the conditions at the time of construction, have significantly deteriorated due to the destructive effect of sea water. Accordingly, the foundations of the enterprise's chemical units, especially those that have undergone modernization with an increase in the beneficial effect on the foundations, need urgent strengthening.

Have been considered aggregates of primary reforming of ammonia, including the furnace of primary reforming in scientific researches [1-2]. Numerical calculations of the finite-element model of the stress-strain state of the structure, made by LIRA-SAPR software have established that the furnace will require reinforcement of both the external supporting frame and the foundations. In [1], it was proposed to carry out reinforcement by installing a monolithic slab, which would allow to perceive additional loads that arose during the reconstruction, as well as to absorb the negative impact from loosening of the soil [1, 3].

However, due to the lack of space, the proposed reinforcement designs cannot be implemented using classic concreting technologies due to the lack of free space under the bottom of the furnace. Therefore, an important scientific task have been arisen to develop an effective technology for construction work in cramped conditions for workers.

Main part of research

In order to fulfill the research task, have been analyzed at which stage of the construction and installation works there is not enough free space. Have been found that there is enough space for the arrangement of reinforcement outlets and reinforcing frames (fig. 1), but at the stage of concreting, the space is extremely insufficient (fig. 2). Workers would have to operate in a lying position on special carts, which is very inefficient and dangerous. Concrete vibration work proved to be problematic, especially in the areas adjacent to the existing furnace columns, which are being reinforced.

Figure 1 – The stage of installation of reinforcing frames of the slab of reinforcement of the foundations of the furnace

Thus, when using classic reinforced concrete [4, 5], the performance of work according to the reinforcement methodology specified in [1, 6] is problematic and extremely time-consuming, requiring the use of additional non-standard equipment or robotic equipment. This significantly increases the cost of construction work.

Therefore, have been offered the technology of concreting without the participation of workers (see fig. 2) under the bottom of the furnace using self-compacting concrete (SCC). The self-compacting concrete mixture is a very mobile rheological substance that is able to fill all cavities without the use of vibration energy and, therefore, without the participation of workers.


Figure 2 – The stage of concreting the foundation slab is strengthened without the use of vibration.

To create such a mixture, various superplasticizer and entraining additives are needed, the amount and content of which depends on the design class of concrete compressive strength, the desired mobility and the additive manufacturer.

Today, in Ukraine and all over the world, superplasticizers from the Swiss company Sika have become the most widely used for the preparation of self-compacting concrete [7]. In China, domestic and foreign production superplasticizers are used, mainly based on polycarboxylates. Superplasticizers make it possible to reduce the water-cement ratio with maintaining high mobility of the mixture, which has a positive effect on the strength of concrete stone.

Air-entraining additives allow for the inclusion of a larger number of air microbubbles in the reaction, which has a positive effect on massive reinforced concrete structures, such as the massive reinforced concrete monolithic reinforcement slab proposed in [1]. As an example Sika Mix Plus is a liquid additive for air entrainment, stabilization and formation of small pores in the structure of construction mortars and concretes. The content of this additive should be within 0.02 – 0.4% of the weight of cement according to the manufacturer's recommendations (for this slab ~ 0,02%).

The additive is recommended in the production of construction mixtures. It helps to increase their plasticity and ease of installation. Well preserves the consistency of construction mortars and the mobility of the concrete mixture during long-term transportation or interruptions in work.

The amount of superplasticizer introduced into the concrete mixture is directly proportional to the amount of cement and ranges from 0,2 to 3%. For self-compacting concrete, this additive is at the level of 1 - 1.5% [7]. For this reinforcement foundation slab have been recommended, a concrete mix with a SikaViscocrete-1020 SK additive content of 1.2%.

In addition, in conditions of a large area and thickness of the slab, have been recommended the use of water-retaining additives, for example, microsilica. The Swiss company Sika recommends the use of microsilica additives of the type SikaFume. The amount of this additive also depends on the mass of cement and, according to the manufacturer's technological map, is 2 – 10%. The introduction of 2% microsilica additive have been recommended for the specified reinforcement slab. The introduction of such an additive significantly improves the density of the concrete structure after hardening, so the slab does not need additional waterproofing.

Existing reinforced foundation structures have been recommended to be coated with adhesive additives such as Sika BetonKontakt, which, in the future, will ensure a reliable connection of fresh concrete reinforcement and old concrete.

Of course, the cost of the resulting concrete mixture is much (up to two times) higher than the cost of classic heavy concrete. However, these overruns more than cover the costs of workers in an uncomfortable semi-recumbent position, and the speed of construction and assembly work is significantly increased.

Acceleration of construction works allows the furnace construction to be put into operation earlier, which will allow the enterprise to produce products and make a profit.

As an alternative to the proposed concreting method could be the technology of robotic delivery of concrete mixture and robotic vibration. However, the cost of transportation and use of the specified equipment far exceeds the increase in the cost of self-compacting concrete.

These recommendations were implemented during the reconstruction of the real furnace structure. All the technological advantages of using self-compacting concrete have been confirmed (fig. 3). The general terms of construction works were reduced by 1 month.

Figure 3 –The finished construction of foundation reinforcement.

Conclusions

Have been obtained an important scientific and practical result, as a result of this research which include technological and materials aspects. This research combines the development of a rational technology for performing work in compressed conditions with minimal use of low-efficiency human labor, the development of recommendations for the use of self-compacting concrete in order to ensure reliable reinforcement of structures where it is impossible to implement work operations and quality control of work performance. The proposed formulation of the mobile concrete mixture and its additives produced by Swiss company Sika.

The effectiveness, reliability and workability of the developed recommendations were confirmed in practice during the implementation of real works on strengthening the foundations of the primary ammonia reforming furnace of the Odesa Port Plant.

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