Mechanization and automation of the process of making concrete mixes

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Abstract. The article addresses the problem of the quality improvement in respect of the concrete mix preparation in the context of intensive mechanization and automation. The co-authors suggest new processes to improve the performance reliability of the operating element of a mixer through the improvement of the wear resistance of its blades. The build-up of the wear-proof layer has boosted the durability of the components of the operating element of a mixer. The logical relationship between the mechanized and automated operations enabled the co-authors to adjust the optimal composition of the concrete mix. The use of composition adjusting devices, operating in the automatic mode, has substantially optimized the process of batching the mix components and the water content in the concrete mix. The co-authors provide a diagram describing the dependence between the mean square value of the outgoing signal of vibration acceleration and the mixing time until the mix is ready. The co-authors have identified that the higher the moisture content, the smaller the mixing time, and, hence, the higher the capacity of a mixer. A hybrid approach to the mix quality improvement has also reduced the operating expenses.

Key words: concrete mixing machine; concrete mix; concrete; mix quality; batching of ingredients; adjustment; batching; grades of concrete; operating expenses.

1 Introduction

The construction boom has boosted the consumption of versatile grades of high-quality concretes. Builders evidence great interest in various grades and types of concretes [1]. It is difficult to produce high-quality grades of concrete, if there is no up-to-date equipment available. The analysis of various types of concrete mixing machines, used to produce concrete mixes, has shown that the design of reliable concrete mixing machines, that have intensive mixing modes of operation, is a relevant task [2, 3, 4]. The reliability enhancement of their operating elements, the automation of mixing modes and the batching of concrete ingredients are the essential objectives to be pursued in the process of preparing different types of concretes and improving their quality [3, 4, 5]. The blades of concrete mixers are subject to the most intense wear during mixing.

A blade is a polygon-shaped element; its reliability improvement must be accompanied by special processing procedures. This element must be resistant to wear and easily

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replaceable, and its operation must be cost effective. An advanced technology was applied to improve the blade's resistance to wear: a layer of wearproof alloys was welded onto their surface. As a result, the durability of the blade of a gravity concrete mixer went up 1.27 times.

2 Materials and Methods

The automatically adjustable homogeneity of the concrete mix is vital issue of production of various grades of concrete [4, 5]. The process equipment, installed at concrete mixing facilities, ensures the acceptable tolerance in terms of concrete mix ingredients and their dozing within the limits of the pre-set standards. Batching accuracy determines the strength and quality of concretes. However, sometimes batching tolerances, even if duly adhered to, cannot guarantee the pre-set quality and the stable production of high performance concrete. Concrete properties diverge from the standard ones in the course of its preparation due to the water batching tolerance. Hence, automated adjustment of the water content in the mix is an important task. In the process of the mix preparation this problem is solved by designing a succession of logically interrelated mechanized and automated operations that include the automated batching of the mix ingredients, primarily, water. [6, 7, 8] In the process of mixing concrete ingredients, it is necessary to identify the minimal time, needed to prepare the concrete with regard for versatile factors, including the optimal homogeneity of the mix. It is important to take account of the moisture content of aggregates, including sand, which requires continuous adjustment of the content of concrete ingredients. Therefore, automated control of the moisture content of aggregates is an essential problem that deals with the optimization of the concrete manufacturing process. The analysis has shown that no effective moisture content control instruments, designated for aggregates, are available today. Any failure to adjust the water content of aggregates, which may reach 10%, causes substantial fluctuations in the strength and workability of the concrete mix. In the course of batching, any excessive water, that cannot be taken account of, can thin the mineral glue, made of cement and water, and reduce the strength of concrete. Presently, the homogeneity of concretes is determined using the sampling method applied in the laboratory environment, which takes too much time and reduces the concrete mix quality. Some manufacturers use automatic water content control and adjustment systems for concretes.

Stetter (Germany), Donner (Austria) integrate water adjustment systems into microprocessor-based control panels designated for ready-mix concrete production facilities.

3 Results

The concrete mix is a complex multi-component system that has cement particles, coarse aggregate particles, water, and air, involved in the mixing process. The mixing process starts when ingredients are fed into the mixer, where particles meet in the process of stirring motion, depending on the shape of a mixer and the optimal arrangement of blades in a drum. In the process of the turbulent motion of aggregate particles, friction and collision forces arise between the particles, the mixer body and the blades, which cause elastic vibrations triggering vibrations of the mixer body and acoustic noises, depending on the physical properties of particles of the mix ingredients. When water is fed into the mixer, the water-cement grout converts the elastic medium into the viscous elastic one in the course of

time, and any changes in this medium influence the characteristics of acoustic and vibrational signals transmitted to the body of the mixer.

An adaptive or self-adjusting automatic control system is considered to be an optimal instrument used to ensure the homogeneity of the concrete mix. It can automatically adjust to new control parameters.

Let's consider the process of mixing the ingredients in a compulsory-type concrete mixer, using vibro-acoustic sensors attached to the mixer body. The mixing time is an unknown variable that depends on the degree of the mixture preparedness. It is influenced by the following factors: sand moisture content, concrete grade, extent of the blade wear, and many others.

4 Discussion

Vibroacoustic sensors allow to compare the actual moisture content of the ingredients with the pre-set one in the process of batching all ingredients. The pre-set moisture content is below the actual one by 17 – 20%, and in the process of attainment of the optimal production capacity, water is fed into the mixer until the concrete mix is ready, while sensors convert vibration acceleration into strain (U). Figure 1 demonstrates the diagram, describing dependence between the mean-square value of outgoing signal (U) and vibration accelerations, on the one hand, and dependence between the mean-square value of the outgoing signal, registered on the surface of the mixer body, and mixing time (T) in case of minimal sand moisture content, $U = f(T)$, on the other hand.

This dependence demonstrates the process of the mix preparation, starting from the feeding of the ingredients and ending with the unloading of the prepared mix with account taken of the fluctuations of vibroacoustic signals that determine the degree of homogeneity. The values of (U), corresponding to the mode of idle run of the concrete mixing machine (section 1-2) and the mode of sand mixing, are minimal, and they rise sharply in the process of sand and crushed rock mixing (section 3-4), and U goes up, as well. When cement is fed into the mixer and mixed with sand and crushed rock, U goes down (section 4-5) due to the damping by the cement of the elastic vibrations emitted by the mixing machine. When water is added, U goes up and down in a while, which indicates the formation of the cement grout and the transformation of the elastic medium into the viscous elastic one. In a while (in 45 seconds after the loading of the ingredients) the value of U stops reducing and the graph demonstrates a stationary vibration mode, which means that the mix is homogeneous and the mixing process is over. As the sand moisture content goes up, the mixing time goes down from 45 to 31 sec. The graph demonstrates that the water, added to the mix, causes a rise (section 1) and a drastic reduction in the (U) value (section 2), which characterizes the process of the cement grout formation. As the time progresses (upon the expiry of 45 seconds after the feed of the ingredients, including water), the reduction in the value of U stops (section 3), and the vibration mode turns permanent, which means that the mix is homogeneous and the process is over.

5 Conclusion

To sum up, a conclusion can be made that the homogeneity of the concrete mix and the optimal concrete mixing time can be identified by the changes in the characteristics of the vibration field. Towards this end, testing and adjustment devices are used and integrated research methods are applied to study the mixing process. This method allows to improve the quality of concrete mixes and the wear resistance of the work tools of a concrete mixer, thus, boosting its capacity.

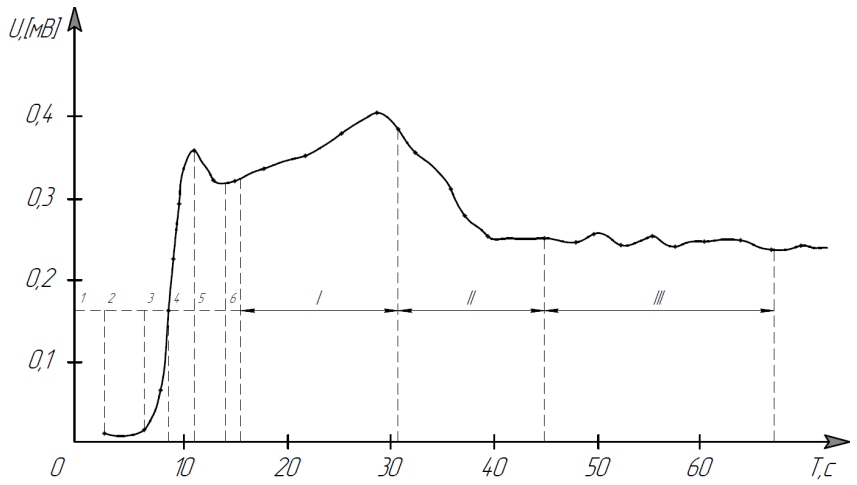

Figure 1. Dependence of vibration accelerations on the mixing time of the sweep components

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