Energy consumption reduction in concrete mixing process by optimizing mixing time

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Abstract

Mixing process plays a very important role in the concrete microstructure, which defines the quality of the final product. The improvement of energy efficiency during this process can help to reduce energy consumption and production costs, without affecting product quality. However, the current concrete mixing practice using an equal mixing time for all batches of each concrete mix design may lead to unnecessary mixing time and energy waste.

The present study investigates the benefit of the mixing time optimization for energy consumption reduction during the concrete mixing process. For this purpose, a reliable method based on mixing power evolution is devised to calculate the shortest necessary mixing time (stabilisation time) of each concrete batch. The batch mixing energy consumption is also determined, through the use of power consumption and the duration of mixing cycle.

Experimental data obtained from 17 concrete batches of two mix designs produced in a full-scale concrete plant were analyzed to figure out the energy consumption difference between the current mixing process of a single mixing time and the one of mixing time optimization. The research results show that by optimizing the mixing time, energy consumption is reduced by about 17% in comparison with the traditional mixing process. Productivity gains are significantly marked by obtaining a reduction in average mixing time of 32%.

Keywords: Mixing time; energy consumption; mixer power measurement; stabilisation time; concrete plant; self compacting concrete

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1. Introduction

Concrete is produced from the combination of aggregates (sand and gravel), cement, water and chemical admixtures. The ready-mixed concrete production includes two main processes: dry batch process and central mix concrete process (also called wet batch process). In dry batch process, concrete components are weighed individually and loaded directly into the truck’s drum mixer which then performs mixing during transportation to the job site. On the other hand, in central mix concrete, raw materials are mixed in the concrete plant by a stationary mixer. Fresh concrete is then transferred to the job site via a truck mixer. While the truck-mixing plant is popular in North America, the entire ready-mixed concrete production in Europe and Japan takes place at central plants [1]. Two important factors affecting the cost of ready-mixed concrete are raw material cost and cost of transportation. Apart from these costs, energy cost occupies a relatively large share of costs in overall manufacturing. Hence, energy saving becomes a vital issue in the concrete industry. This paper focuses on the energy saving for concrete production in central mix plant. As the mixing process represents a key role in the product’s microstructure which defines the quality of the final product, in this paper, emphasis is put on the mixing energy consumption.

In several concrete plants, mixing energy requirements are determined by the power consumption curve (power consumption vs. mixing time) which is used to monitor the concrete evolution during mixing. Given the variability of aggregate water content during industrial production, the use of this curve enables controlling batch water content and then regulating this composition in the mixing truck by adjusting the amount of water to be added in following batches [2, 3]. Indeed, when the mixing power measurement reaches a plateau (i.e. no significant change in power consumption), it is considered that concrete homogeneity is reached [4] and the water content of the mixed batch can be estimated. Besides, by tracking the time required to attain the power consumption stabilisation, different concrete mix designs need different mixing times to achieve optimum flowability [5]. This remark is also valid for the same given concrete mix design, i.e. different mixing times are required for batches containing different water contents.

However, the current mixing process consists of setting an equal mixing time for all batches within a given mix design in order to assure obtaining a compliant concrete for a majority of plant outputs. Such a production strategy may lead to unnecessary mixing time and energy waste when the mixing time needed to produce a homogeneous and uniform mix is less than that programmed in the concrete recipe. In this context, the authors propose a method of mixing time optimization by setting the shortest necessary mixing time as the sufficient mixing time of each concrete batch. The proposed method is compared with the current one of a single mixing time through experimental data obtained from a number of concrete batches within a full-scale concrete plant with the aim to advance in quantifying the difference in mixing times and energy consumptions. The authors strive to reduce mixing time and mixing energy consumption by limiting mixing time for each concrete batch to just what is adequate.

### Nomenclature

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>SCC</td>
<td>self-compacting concrete</td>
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<tr>
<td>Ts</td>
<td>stabilisation time of power curve (s)</td>
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<tr>
<td>Tm</td>
<td>mixing time (s)</td>
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<tr>
<td>ΔT</td>
<td>mixing time difference between the mixing process of a single mixing time and the one of mixing time optimisation (s)</td>
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<tr>
<td>ΔE</td>
<td>energy consumption difference between the mixing process of a single mixing time and the one of mixing time optimisation (Wh)</td>
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2. Experimental methods

2.1. Concrete composition

In this study, a total of 17 batches from different mix designs have been analyzed. Two self-compacting concrete recipes, i.e. an innovative concrete that does not require vibration for placing and compaction (SCC-A and SCC-B see Table 1) are mainly introduced and the water content was varied from one batch to the next. In order to reduce...
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