Advanced Pavement Research

Edited by
Bo Tian and Kaimin Niu

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Advanced Pavement Research

Selected, peer reviewed papers from the
3rd International Conference on
Concrete Pavements Design, Construction, and Rehabilitation
(ICCPDCR 2013),
December 2-3, 2013, Shanghai, China

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Preface

The present volume contains selected papers from the 3rd International Conference on Concrete Pavements Design, Construction, and Rehabilitation (ICCPDCR). The conference is organized and co-organized by Research Institute of Highway, Ministry of Transportation (RIOH), Road Branch of China Highway & Transportation Society, Key Laboratory of Road Structure & Material of Ministry of Transportation and National Engineering Laboratory for Surface Transportation Weather Impacts Prevention.

The International Conference on Concrete Pavements Design, Construction, and Rehabilitation is a biennial conference inaugurated in 2009. The past two conferences were successfully held in Haikou, and Shenzhen. They have provided excellent platforms for participants to exchange their new ideas and have brought forth new research opportunities and collaborations. The 3rd conference will be held in Shanghai, China, during December 2-3, 2013.

This volume presents a selection from papers submitted to the conference from universities and industries. All of the papers were subjected to peer reviewing by at least two expert referees. The papers selected for this volume depended on their quality and their relevancy to the conference. It is therefore valuable to production and research engineers, research students and academics in the field.

We would like to express our sincere appreciations to all the authors for their papers and presentations in this conference. We wish to thank the members of the scientific committees and invited referees for their assistance in reviewing the abstracts and full papers. We are grateful to all the invited speakers who came to share their knowledge with us. We hope that this book will not only provide the readers a broad overview of the latest advances but also provide the researchers a valuable summary and reference in this field. Finally, special thanks are given to Trans Tech Publications for producing this volume.

The Organizing Committee of the 3rd ICCPDCR

Conference Organizers

Research Institute of Highway, Ministry of Transportation
Road Branch of China Highway & Transportation Society
Key Laboratory of Road Structure & Material of Ministry of Transportation
National Engineering Laboratory for Surface Transportation Weather Impacts Prevention.

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CHAPTER 1:

Pavement Materials

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Study on Test Methods for Intelligence-based Monitoring of Fresh Cement Concrete Quality

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Keywords: road engineering, test method, fresh cement concrete, quality monitoring, torque, current

Abstract: A test method for monitoring of cement mortar quality has been devised and an empirical relational equation between cement mortar fluidity and torque has been worked out. A test method for monitoring of indoor fresh cement concrete quality has been devised and a relational equation between fresh cement concrete and torque has been worked out. A test method for monitoring of fresh cement concrete in a mixing plant has been devised and a relational equation between fresh cement concrete and current property has been worked out. By means of online observed torque and current data, relevant fluidity and slump can be predicted to provide test methods and relevant theoretical basis for intelligent monitoring of fresh cement mortar and cement concrete quality in actual engineering.

0 Introductions

For fresh cement concrete, a common way to control it is to control the slump of concrete coming out of the plant and quality monitoring is relatively lagging. In actual engineering operations, it's impossible to control the slump of each load of concrete; in the meantime, a majority of fluctuating fresh concrete has to be used except for extraordinary deviation from normal slump. Intelligence-based monitoring is an effective way to study the workability of fresh road cement concrete [1,2,3].

At present, the biggest obstacle to fresh cement concrete quality monitoring is discreteness caused by aggregate, i.e. uneven distribution of aggregate in mortar, which consequently results in the difficulty to monitor and test cement concrete[4,5,6]. For this reason and for purposes of better control of concrete quality, our tests started from cement mortar and deepened step by step to study indoor fresh cement concrete and fresh cement concrete in a mixing plant, probe into test methods for intelligence-based monitoring of fresh cement concrete quality, and realize intelligent control of fresh cement concrete largely by online monitoring of torque and current properties during agitation, by online analysis as to whether or not fresh cement concrete has been evenly mixed, and by predicting the slump of cement concrete.

1 Technical performance of raw materials

(1) Cement

Jinyu branded 42.5 ordinary Portland cement was used. Its physical properties are shown in Table 1.

Table 1 Physical properties of cement

Strength grade	Stability	Water usage at normal consistency (%)	Specific surface area (m^2/kg)	Setting time (min)		Compressive strength (MPa)		Flexural strength (MPa)		Apparent density (g/cm^3)
				Initial setting	Final setting	3d	28d	3d	28d	
42.5	Acceptable	28.6	355	199	266	34.6	56.6	6.1	9.2	3.00

(2) Water

Tap water for labs in accordance with the provisions of current national standard GB5749, "Sanitary Standard for Drinking Water".

(3) Fine aggregate

Fine aggregate was medium sand with fineness modulus of 2.67, apparent density of 2.65 g/cm3 and grading limit in accordance with the zone II grading requirement in GB/T 14684-2001, "Sand for Building".

(4) Coarse aggregate

Coarse aggregate was 4.75 mm-31.5 mm continuously graded limestone rubble with apparent density of 2.69 g/cm3, crushing value of 15.5%, soundness of 4.2% and silt content of 0.5%.

(5) Admixtures

Two water reducing agents and two air entraining agents were used in the tests. These were a naphthalene series solid-state water reducing agent, a polycarboxylic liquid-state water reducing agent, a saponin type solid-state air entraining agent and a PL liquid-state air entraining agent respectively.

2 Test method for monitoring of fresh cement mortar quality

2.1 Test method

To avoid the effect of aggregate discreteness on monitoring of fresh cement concrete mixture quality, a test method for monitoring of cement mortar quality was studied first of all. Cement mortar is apparently the most important and most complex ingredient of fresh cement concrete and is homogeneous within the scale of an indoor cement mortar mixer. Study on cement mortar quality monitoring technique can provide an excellent methodological basis for fresh cement concrete quality monitoring technique [7,8,9,10].

The study altered an existing cement mortar mixer by adding a torque sensor to realize the function of online torque measurement, as shown in Fig 1. The device realized real-time acquisition of torque during agitation of cement mortar and its fluidity was tested according to the cement mortar fluidity determining method in the Test Code for Cement and Cement Concrete for Highway Projects (JTG E30-2005) [11]. By establishing a relation between fluidity and torque, a test method basis has been provided for monitoring of cement mortar quality.

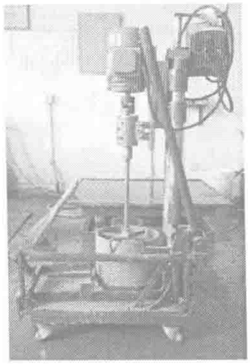

Fig. 1 Picture of physical torque tester for cement mortar

2.2 Relation between cement mortar fluidity and torque

By means of the torque tester for cement mortar and relevant test method, the relation between cement mortar fluidity and torque was studied. The test set the rotating speed at 180 r/min, i.e. at shear rate of 18.84 (1/s). The reference mixing proportion for the test is shown in Table 2.

Table 2 Reference mixing proportion for the test

Designation	Water	Cement	Sand
Dosage (g)	225	450	1,350

The study started from onefold variables and went on by corresponding to different groups of cement mortar with changed water usage, cement usage and sand usage. The relation between fluidity and torque, as obtained from the test, is shown in Fig 2.

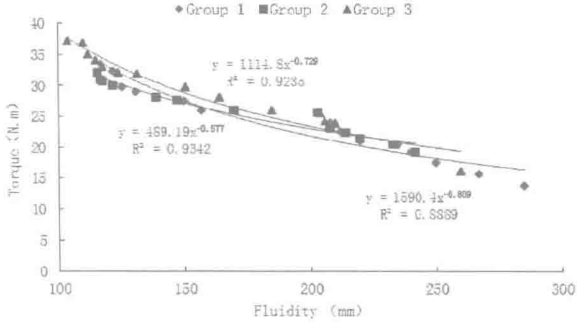

Fig. 2 Chart of relation between cement mortar fluidity and torque

It can be known by analyzing the test results that the fluidity of cement mortar manifests a tendency of decreasing with increasing torque value and that the relation between the two can be expressed approximately by a power function. It's practicable to study the relation between cement mortar fluidity and torque using this method which applies to cement mortar with fluidity in the range of 100 mm-300 mm. To establish a more precise relation between cement mortar fluidity and torque value, accumulation of substantial relevant data and further validation in actual operations are required, of course. This empirical method, however, achieves the objective of predicting cement mortar fluidity with torque value to some extent, which provides an excellent test method and theoretical basis for online control of cement mortar quality.

3 Test method for monitoring of indoor fresh cement concrete quality

3.1 Test method

For better study on a test method for monitoring of fresh cement concrete quality, a concrete agitator commonly used in labs was altered, the agitating manner of mixing plants in actual engineering simulated, double horizontal shafts used for agitation, and a transducer and torque sensor added for use in adjusting rotating speed during agitation and determining torque value during agitation respectively [12,13,14,15]. The double-horizontal-shaft agitator used in the test is shown in Fig 3, which realized real-time acquisition of torque speed during concrete agitation.

Fig. 3 Picture of physical double-horizontal-shaft cement concrete agitator

Based on the cement concrete slump determining method in the Test Code for Cement and Cement Concrete for Highway Projects (JTG E30-2005), the slump value can be obtained and, accordingly, the relation between torque and slump can be established, which consequently provides a test method basis for monitoring of fresh cement concrete quality.

3.2 Relation between indoor fresh cement concrete slump and torque

To realize monitoring of fresh cement concrete quality and predict its slump, a double-horizontal-shaft cement concrete agitator was used to study the relation between slump and torque. There are many factors that have an effect on fresh cement concrete slump and torque, and the type and usage of each ingredient can cause a change in slump and torque. Therefore the tests started first from onefold variables; in other words, testing was taken on different factors respectively, including water, cement and rubble, by changing the usage of only one ingredient in each test group. The reference mixing proportion used for the test is shown in Table 3. During the tests, torque value and relevant slump after even agitation at constant rotating speed of 48 r/min were determined and relevant relation between the two was established, as shown in Fig 4.

Table 3 Mixing proportion for the tests

Kind	Cement	Water	Sand	Bigger rubble	Medium rubble	Smaller rubble
Mixing proportion (Kg/m^3)	365	242	810	296	496	197

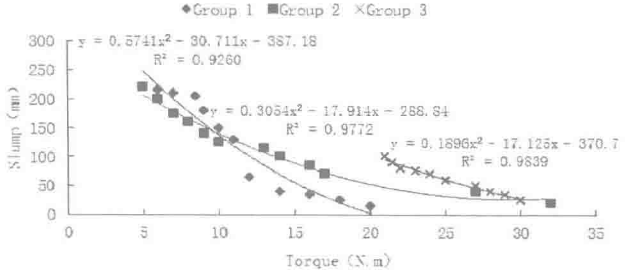

Fig. 4 Relation between slump and torque

By analyzing the test results, it can be seen that an approximate polynomial relation is manifest between fresh cement concrete slump and torque. Its slump manifests a tendency of decreasing with increasing torque. In actual engineering, torque value after even agitation and slump value after coming out of the plant remain constant as well for cement concrete with same mixing proportion so that a certain fixed mixing proportion can be calibrated and concrete slump and torque remain unchanged as long as materials used remain unchanged. Therefore the quality of fresh cement concrete can be monitored by means of online observation of torque value. If there is a considerable error between observed torque value and the torque value at calibration, the quality of fresh cement concrete may be considered as not in conformity with requirements; at this point, the whole process should be examined to find and solve any problem timely and ensure concrete quality.

4 Test method for monitoring of fresh cement concrete quality in a mixing plant

4.1 Test method

Adoption of torque measurement on an indoor double-horizontal-shaft agitator is an effective method. It's very difficult to realize installation of a torque measuring device and taking relevant tests on a large mixing plant. And it was observed during the torque measurement test that current data showed features similar to torque data during concrete agitation, whereas it's relatively easier to realize acquisition of current data on a mixing plant; therefore the method of current measurement was chosen for study of concrete agitation process in a mixing plant [16,17,18]. A current acquisition and storage unit was used in the test, as shown in Fig 5. Current data can be acquired during a test by attaching the current acquisition unit to a mixing plant and the value of slump after coming out of the plant can be determined according to the cement concrete slump determining method in the Test Code for Cement and Cement Concrete for Highway Projects, from which the relation between the two can be analyzed and established and a theoretical basis provided for monitoring of fresh cement concrete quality in mixing plants.

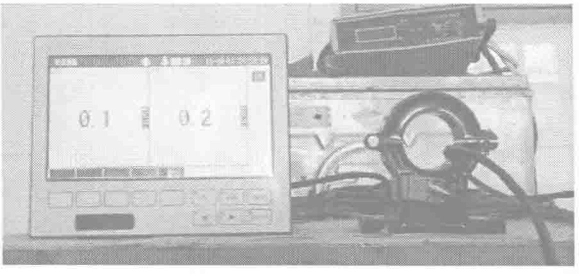

Fig. 5 Current data acquisition and storage unit

4.2 Relation between fresh cement concrete slump in a mixing plant and current

Slump has been widely applied as quality control index for concrete coming out of mixing plants and concrete on construction sites. Establishment of the relation between the stable value of current during agitation and slump allows judgment, by means of online observed current data, as to whether or not concrete has been evenly agitated as well as judgment as to whether or not the workability of concrete coming out of a plant meets requirements, whereby to realize monitoring of fresh cement concrete quality. The reference mixing proportion used in the tests is shown in Table 4. Different studies of changes in cement, sand and rubble usages respectively were performed and relevant relation between current and torque data was obtained, as shown in Fig 6.

Table 4 Mixing proportion for the tests

Ingredient	Cement	Water	Sand	Medium gravel	Small gravel
Mixing proportion (Kg/m^3)	410	168	625	795	427.5

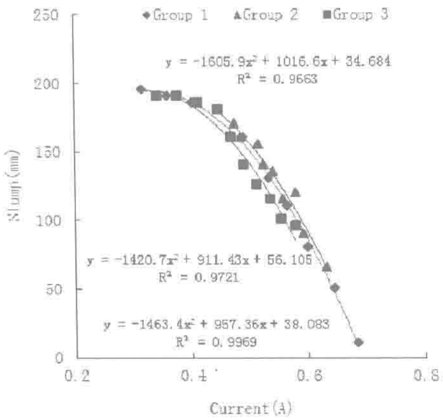

Fig. 6 Relation between current value and slump

By analyzing the test results, it can be known that a polynomial relation is manifest between current value and slump after cement concrete has been evenly agitated and that the method can be used to approximately predict the slump of fresh cement concrete in a mixing plant, which indicates the practicability of online monitoring of the quality of cement concrete in a mixing plant with current data. In actual engineering, there are many factors that have an effect on current; in addition to the materials concrete itself is made of, these include different agitating equipment and external power supply. Therefore comprehensive consideration should be given to the effect of various factors when the quality of cement concrete is monitored by applying current data, and the interference of external factors should be avoided at the same time as far as possible to ensure the accuracy of current data.

5 Conclusions and suggestions

(1) A test method for monitoring of cement mortar quality has been devised and an empirical relational equation between cement mortar fluidity and torque has been worked out. The fluidity can be approximately predicted by means of relevant online observed torque, which provides relevant theoretical basis for monitoring of cement mortar quality.

(2) A test method for monitoring of indoor fresh cement concrete quality has been devised and a relation between fresh cement concrete and torque has been worked out. The slump of concrete coming out of a plant can be approximately predicted by means of online observed torque after even agitation, which provides a theoretical basis for intelligent monitoring of fresh cement concrete quality.

(3) A test method for monitoring of fresh cement concrete in a mixing plant has been devised and a relation between fresh cement concrete and current property has been worked out. The slump of concrete coming out of a plant can be approximately predicted by means of online observed value of current feature after even agitation, which provides a test method and relevant theoretical basis for intelligent monitoring of fresh cement concrete quality in actual engineering.

In actual operations, there are many factors that have an effect on torque and current data. The relational equations between torque and fluidity, between torque and slump and between current and slump, as established through the tests, are empirical formulas the scope of application of which has yet to be studied.

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