THE NEW TEST TECHNOLOGY FOR EVALUATING THE ANTI-CRACKING PERFORMANCE OF CONCRETE RUNWAY OF THE AIRPORT UNDER CONSTRUCTION

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ABSTRACT

This article develops one new test technology for evaluating the anti-cracking performance of concrete runway of the airport under construction. This dumbbell test technology can help evaluate the effects of different factors on the anti-cracking performance of concrete runway with the new device of stress riser. By this method, the anti-cracking performance of runway of different concrete material can be evaluated quickly in the construction site. This new test technology can provide solutions to choosing the most suitable material and concrete mix ratio to improve the anti-cracking performance of concrete runway under construction. The paper also conducted a comparative study with the other two test methods of concrete anti-cracking performance (ring method and slab test method) under constraint conditions.

Key words: Airport runway; Crack; Stress riser; Dumbbell method; Slab method; Ring method

1. INTRODUCTION

In recent years, the phenomenon of airport runway surface cracking has become a universal problem. The increasingly worsening of cracking brings durability destruction and structural damage. Among the reasons causing runway cracking, materials is the most important factor. Different from the results obtained in laboratory, there are more influence factors causing the runway cracking in construction site. In the airport construction condition, the concrete material with highest anti-cracking performance will be the best material for airport runway, while meeting the requirements of the strength and durability index. Therefore, we need the test method that can evaluate the anti-cracking performance of concrete quickly and accurately in the airport construction condition.

The cracking performance of concrete testing under constraint condition is more close to the condition of concrete in the construction site. Until now; there isn't any standard method to test the cracking performance of concrete under constraint condition in National standards. All methods around globe are in trial and people still could not reach conclusion. [1]

The methods of testing the cracking performance of concrete under constraint conditions mainly include Slab Method, Ring Method and Prism Method. Although these three

methods could solve certain problems, they also have major problems. Slab Method, introduced by Kraai in 1985[2], couldn't precisely evaluate the crack of concrete due to the irregularity of crack, and its data processing afterwards has drawbacks. Ring Method was introduced by Roy Carlson from MIT in 1942[3] and the problem of Ring Method is the long time that takes to test and its lack of sensitivity. Prism Method was invented by Springenschmid from German in 60s of 20c[4], which can test the trend of concrete crack, however it is inconvenient to test at job site, expensive, and its instruments require high sensitivity.

In order to overcome limitations mentioned above, this research developed a new method to evaluate the crack performance of concrete under constraint conditions. Its exercise of stress risers could lead concrete to crack quickly, providing a quick method to evaluate the crack performance of concrete material and to perform simulated test at job site conveniently.

2. A NEW TEST TECHNOLOGY-DUMBBELL METHOD UNDER CONSTRUCTION CONDITION

This paper proposes a new test technology, Dumbbell method, for evaluating the anti-cracking performance of concrete under constraint conditions (Figure 1), based on which, Dumbbell device with stress riser for concrete crack test is invented. From the principles of view, the device is equipped with advanced Stress cracks generator systems, which can induce the crack. In addition, the ends of the device can provide the constraint, which makes concrete crack. This method proves to be more effective for the quick crack, after times of experiment and comparison of different methods in the same condition. The structure of the instrument is shown in the following sketch.

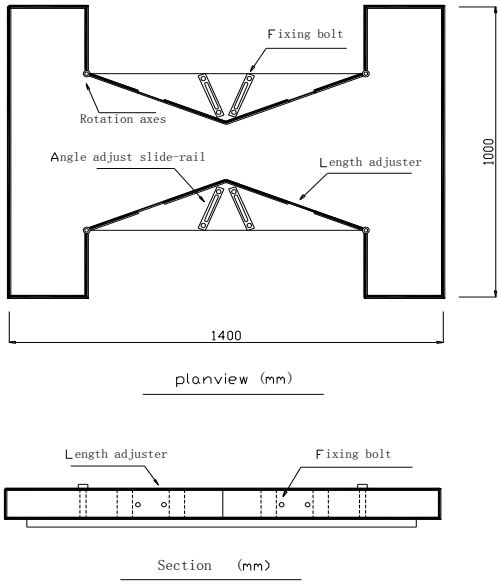

Figure 1 - Dumbbell device with stress riser for concrete crack test

On both sides of the central device are stress risers for which angle can be adjusted. After concrete is poured into the mold, stress concentration is generated under induction of the stress risers and the ends of the mold can provide the constraint. The stress, due to restrained volume change related to deformation and shrinkage of concrete, is the main driving force for the deleterious cracking. When concrete Shrinkage stress is greater than resistance, the specimen will crack.

Test mold of the device is made of steel, which includes both sides of the fixed-end and adjustable stress generator in the middle. Adjustable angle of stress generator can be adjusted freely within a certain range. The narrow angle will make concrete material lose specimen representation and too big angle will affect the sensitivity of the test specimen. Therefore, the adjustable stress generator will get the most suitable angle for concrete cracking. After the determination of the best angle of stress generator, all parts of the instrument should be fixed and crack test can be carried out. This method is suitable for the evaluation of the early age concrete cracking performance with the following advantages: stronger sensitivity, more accurate, and easy to use at the construction site.

3. EVALUATION INDEX AND DATA PROCESSING OF DUMBBELL METHOD

There are two Evaluation indices for the dumbbell method. One is ICT (Initial crack time), the other is ACW (average crack width within 24 hours).

(1) Index of ACW(average crack width within 24h)

24 hours after concrete pouring into the mold, the single crack is divided into six equal portions by five line segments. Then, record the crack width of the five crossings of crack and line segments. The average width of the five widths is ACW (Average Crack Width within 24h)

$$W = \frac{1}{N} \sum_{i}^{N} Wi$$

Wi—the crack width of the No.i line segment, mm.
N—number of the line segments (N=5 in this article)

(2) Index of ICT (Initial Crack Time)

ICT (Initial crack time) is another important index of concrete cracking performance. The later the concrete crack, the better the anti-cracking performance of concrete. It indicates the beginning of the test time when concrete is poured into the mold and make a careful observation of appearing of the crack, then set the appearing time as ICT(Initial crack time) of the test,(h:min).

4. COMPARATIVE STUDY OF THREE ANTI-CRACKING PERFORMANCE EVALUATION METHODS UNDER CONSTRAINT CONDITIONS

Slab method uses a concrete slab (600mm×600mm×63mm) [5]. The steel bolts around the mold restrict the concrete shrinkage after pouring the concrete (Figure 2). When concrete Shrinkage stress is greater than resistance, the concrete specimen will begin to crack. Evaluation index of slab method are the Average Square of the cracks, the number of the cracks and Total Square of the cracks.

Figure 2-Slab test method for Concrete crack test (Kraai)

Mold of Ring method includes inner steel ring, outer ring and the base (shown in Figure 3). Because the stiffness of steel ring is large, ring can provide the restriction for concrete specimen when concrete shrink. Crack will happen from the interface of the specimen under the tensile stress [6] caused by the constraint of the ring. Evaluation Index of slab method are initial time to crack and average crack width.

Figure 3-Schematic of Ring Set Up for Concrete crack test

Test mold of dumbbell method includes both fixed-ends and adjustable stress riser in the middle. Stress concentration is generated under induction of the stress risers and the ends of the mold can provide the constraint. The stress, due to restrained volume change related to deformation and shrinkage of concrete, is the main driving force for the deleterious cracking. When concrete Shrinkage stress is greater than resistance, the specimen will crack. This method is suitable for evaluation of the early age concrete cracking performance has the following advantages: stronger sensitivity, and more accurate, but also easy to use at the construction site. Evaluation Index of dumbbell method are ICT (Initial crack time); ACW (average crack width within 24h).

Figure 4-test Photo of dumbbell method with strength riser

(1)Materials

The cement used was P.O. 42.5 Portland cement produced by Xingfa Cement Ltd. in Beijing. Coarse aggregate used in test is limestone gravel from Beijing Mentougou district, which size is 5 ~ 25mm in continuous gradation, the apparent density is 2760kg/m^3 and ACV is 6.1. Fine aggregate used in test is sand from Qinhuangdao with fineness modulus of 2.8. Fiber used is cellulose fiber produced by Shanghai Royang material company.

(2)Test Object and Test Methods

Test object is to perform the comparative study of three anti-cracking evaluating methods under constraint conditions including slab method, ring method, dumbbell method.

(3)Mix Proportion

This study prepares three test groups of C30 concrete with the Mix proportion, shown in table 1. Each mix proportion was tested by three methods. The preparation of fiber reinforced concrete designed to compare sensitivity of three kinds of crack test method because of the good anti-crack performance of fiber reinforced concrete. Fiber used is cellulose fiber and dosage is 0.9kg/m^3, 1.2kg/m^3, 1.5kg/m^3. Tests were carried out at constant temperature and humidity chamber in which the temperature is maintained at 30 ± 2 Centigrade, relative humidity is maintained at 50 ± 5%.Under the same test conditions, each ratio of concrete is used to test three methods to study three kinds of testing method for concrete cracking evaluation.

Table 1-Mix proportion of concrete and other test parameters

Material (kg/m^3)					Slump (mm)	Slump Flow (mm)
Cement	Sand	Gravel	Water	Fiber		
360	796	1099	145	0.9	210	400/400
360	796	1099	145	1.2	200	460/460
360	796	1099	145	1.5	205	440/460

(4)Results and Discussion

For the fiber reinforced concrete with different fiber dosages, dumbbell, slab and ring methods have shown the same restraint cracking tendency .For concrete with dosage for 1.5kg/m^3, the ICT (Initial crack time) is the longest ; ACW (average crack width within 24h) is the smallest. For dosage for 0.9kg/m^3, the ICT (Initial crack time) is the shortest; ACW (average crack width within 24h) is the Widest. For fiber reinforce concrete, this test result is consistent with theoretical analysis and practical test result. Therefore, the evaluation result for assessing concrete cracking performance by using these three kinds of test method is accurate.

Table 2-Result of the crack test with the three methods

(ICT=Initial crack time; MCW= Maximum crack width)

Dosage		dumbbell	slab	ring
1.5kg/m^3	ICT	2h:15min	2h:30min	6d
	MCW	0.96mm	0.67mm	0.34mm
1.2kg/m^3	ICT	1h:50min	2h:10min	4.5d
	MCW	1.13mm	0.88mm	0.59 mm
0.9kg/m^3	ICT	1h:25min	1h:50min	4d
	MCW	1.34mm	1.09mm	0.81mm

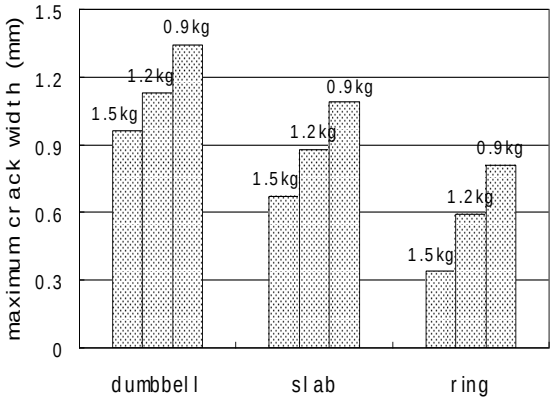

Figure 5. Maximum crack width of concrete with the method (dumbbell、slab、ring)

From the test results(shown in table 2), for concrete with dosage for 1.5kg/m^3, concrete crack first by dumbbell method which is superior to slab method and ring method(Figure 5). The initial time of the ring method is much later than the former two kinds of methods. From view of the maximum crack width, it is 1.07mm by using dumbbell method, which is much

larger than the other two methods, 0.64mm and 0.52 mm. The concrete with dosage of 0.9kg/m^3 and 1.2kg/m^3 also shows the same trend. The concrete cracking performance can be reflected more obviously with larger Maximum crack width which makes the crack measurement easier and can reduce the measurement errors.

For the same test material, among the three kinds of methods, dumbbell method is the fastest method to reflect the concrete cracking performance and the maximum crack width is the Widest. So from the view of sensitivity, dumbbell test method is superior to slab and ring method for evaluating the concrete crack performance.

From the view of test cycle, it need 24h to finish the test by dumbbell method and slab method; Because of the less sensitivity, ring method need longer time to finish the test when the initial crack occurs. In this study, it needs 4d to complete the test by ring method. Therefore, dumbbell method and slab method are superior to ring method in the test cycle.

Figure 6- test photo with three methods (dumbbell、slab、ring)

From the view of crack measurement operation, concrete specimen shows one crack by dumbbell method and ring method, which is easy to measure the width of the crack and determine the initial time of the crack (Figure 6). As for the slab method, on the specimen, there are many cracks, which are hard to identify and measure. Therefore, dumbbell test method and ring method are superior to slab method for evaluating the concrete crack performance in the crack measurement operation.

Table 3- Overall comparison of the three test methods

	dumbbell	slab	ring
sensitivity	good	above average	average
testing cycle	short	short	long
operability	good	average	above average
Application on job site	good	above average	average

As for the application on job site, dumbbell method and slab method are able to reflect the concrete crack performance in a relatively short time because of their strong sensitivity,

which is most important for application on construction site. Therefore, lateral comparative test can be performed conveniently on job site. Ring test method is seldomly used because of its long test cycle, which cannot meet the requirement of the construction site. Overall comparison of the three test methods is shown in table 3.

5. CONCLUSION

From the view of sensitivity, test cycle, operability, applications on construction site, the dumbbell method is superior to slab method and ring method. Dumbbell method is suitable for evaluating the early age concrete cracking performance with the following advantages: stronger sensitivity, and more accurate, and convenient application on construction site.

REFERENCES

1. Yan Liu，Peiming Wang，Study on the Slab Test technology of Concrete Anti-Cracking Performance with the method of stress risers，Journal of Bulding Material,2006,12:12-16
2. Kraai p. A Proposed Test to Determine the Cracking potential due to Drying Shrinkage of Concrete. Concrete Construction,1985 ;30(9):775
3. Standard Practice For Estimating The Cracking Tendency Of Concrete，AASHTO Designation:pp.34-99
4. Edited by R. Springenschmid etc, Thermal Cracking In Concrete At Early Ages, E&FNSPON, 1994
5. Design of Concrete Structure Duribity and Guide for Construction，Beijing, China Building Industry Press, 2004, pp.33-34
6. Wiegrink K, Marikunte S, Shah S P, Shrinkage cracking of high strength concrete，ACI Materials Journal,1996;93(5):409-415