A new method to determine the thermal dilation coefficient (TDC) of cement-based material at early-age

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ABSTRACT: At early-age the thermal deformation of cement-based material is an important composition of the total deformations, which may lead to the early cracking. To quantify the early TDC of cement-based material by measurement is a prerequisite to formulate numerical models used in early cracking calculation. However, the value of early TDC reported in the literature reveal large deviations. So the present paper firstly summed up the actuality of the measurement of early TDC of cement-based material, then analyzed some factors, which may result in measuring errors, finally a novel apparatus and its application for measuring the TDC of cement-based material at early-age are presented. Using this new method, TDC of cement-based materials can be measured rather accurately from early-age, with adequate consideration of temperature history.

1 INTRODUCTION

At early-age the thermal deformation of cement-based material is an important composition of the total deformations, which may lead to the early cracking. To quantify the early TDC of cement-based material by measurement is a prerequisite to formulate numerical models used in early cracking calculation. However, the value of early TDC reported in the literature reveal large deviations. And since there are abundant difficulties in measuring the TDC of cement-based material at early-age, up to now only a few researchers have carried on this kind of experiment, and the methods as presented in different publication varies enormously.

2 CAMPARISON AND SUMMARY OF THE ISSUED EXPERIMENT RESULTS

From the 1870's now, TDC of cement-based material has been determined. But most of these experiments were carried on the mature cement-based. The real measuring of TDC of early-age cement-based material began from 1980's. The TDC of early-age concrete had been measured by ACI committes517 (1980), Miao et al (1993), Laplantel et al (1994), Bjøntegaard et al (2001), & Kada et al (2002). The TDC of early-age mortar had been measured by Loukili et al (2000) & Turcry et al (2002). The results of each experiment are showed in Figure 1. The key contents of each experiment are showed in Table 1.

Seeing from the curves in Figure-1, all experiment results reflect a same trend that the TDC at early-age has a very high value, but drops significantly through setting, after setting still changes with age, but the variety magnitude is small. At the same time the curves in Figure-1 also reflected the following problems.

1 For the TDC-age relation curve of the cement-based material, different researchers' results are very diverse. For example the beginning time of determining is not same, the TDC' s minimum, maximum and the stable magnitude are not same not only in value but also in the occurrence time, the slope and magnitude of those curves are not same too. Just because there are so many contradictions in delivered literatures, a conclusion on the behavior of the TDC can not be made, up to now.

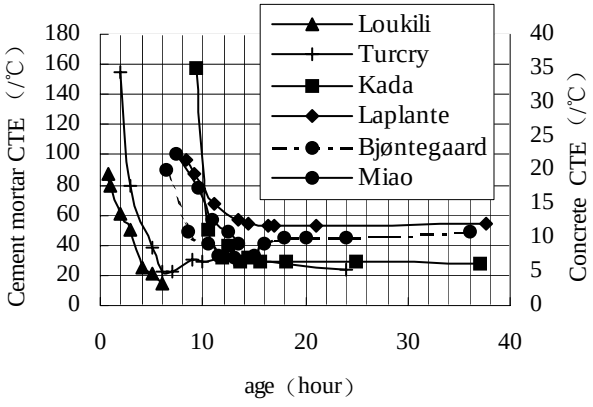

Figure 1. Results of each experiment.

Table 1. The key content of each experiment

Key contents	Author					
	Loukili	Turcry	Kada	Laplante	Bjøntegaard	Miao
Specimen type	Cement mortar	Cement mortar	Concrete	Concrete	Concrete	Concrete
W/c-ration	0.35	0.25	0.5	0.45	0.4	0.28
Deform measuring instrument	Hydrostatic weighing	Hydrostatic weighing	Vibrating wire extensometer	extensometer	exterior LVDT	extensometer
Heat controlling instrument	Heat-controlled water bath	Heat-controlled water bath	Two fixed temperature water bath	No Temperature equipment	Water circulation in copper cube	No Temperature control equipment
History of curing temperature	Realistic temperature history	Realistic temperature history	Alternate between 10 and 50 temperature	Isothermal temperature	Realistic Temperature history	Realistic Temperature history
Magnitude of temperature change	10℃	3-4℃	40℃	Continuous temperature change	3.5~10℃	Continuous temperature change

2 There are a great many factors, which can affect the TDC of cement-based material at early-age. In terms of the specimen itself, there are these affecting factors such as water cement ratio, the type of aggregate, the content of aggregate, the size of specimen, the age of specimen, and so on. In terms of external environment condition, the curing temperature history and the curing humidity history will affect the development of TDC. In terms of determining and calculation, there are these affecting factors such as the mode of temperature change, the range of changing temperature, the time of determining, the method of eliminating other deformations, and so on. These factors are all incompletely same in each experiment, so the analysis on influence mechanism and influence magnitude of each factor is very difficult to be carried on, with these experiment results. Thus, a more systematical experiments, which will take all kinds of affecting factors into account, are needed to be done to reveal each factor and factors' s influence mechanism and influence magnitude.

3 Some aspects in the experiment need to be improved, such as earlier start time of measuring, more complete elimination of other transformation, more accurate monitoring of temperature consistency in specimen, and so on.

3 SUMMARY OF THE EXPERIMENT SCHEME

If an experiment scheme is selected to measure the TDC of cement-based at early-age, it must possess of the following characteristics.

1 Because the strength of early-age cement-based is very low, the extensimeter, which is putted in the interior of specimen, can not measure the deformation of the specimen accurately at early-age. Thus the external LVDT should be used to measure the deformation at early-age.

2 Measuring deformation through the exterior LVDT demand that specimen can deform freely, but at early-age the cement-based materials need the formwork to support itself' s weight. So a new die should be designed to realize measuring deformation with formwork or with parts of formwork.

3 Because of the low strength and Young' s modulus, any exterior constraint will produce big influence on the specimen's deformation, so any fiction, which may exist, should be eliminated as far as possible.

4 Because a set range of even temperature variation is demanded as quickly as possibly, the cross-section size of the specimen should be as small as possible. And the heating velocity of the heating equipment should be quick.

5 The temperature history used in experiment should imitate the temperature history of the actual structural unit, so the result gotten from the experiment will have a larger practical value.

6 Various modes of changing temperature, from simple one to complicate one, should be designed to reveal the influence mechanism and the influence range of some factors.

4 INTRODUCTION OF THE NEW EQUIPMENTS

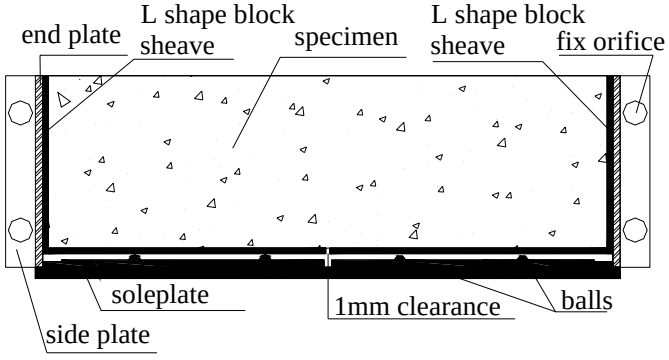

Figure 2. Die of casting specimen.

The total experiment equipments are constituted of three parts, die of casting specimen, temperature controlling equipment and displacement measuring equipment. The die of casting specimen are constituted of soleplate, detachable side panel, detachable end plate, two L shape block sheaves and six balls. The soleplate has six spherical guides in which ball can move freely, see Figure 2. The temperature controlling equipment can be some kind of baking box which can carry out some certain functions such as changing the temperature according to designed curve, sustaining a isothermal temperature, and so on. Displacement measuring equipment is constituted of electro magnetic strain gage, and automatic register device. The advantages of these apparatuses lie in the following aspects.

1 The design of the block sheaves and ball-bearing change the stress boundary condition and make for the specimen's free deforming when the friction force can not be eliminated absolutely. Thus using this design can solve the problem how to accurately measure the deformation when the strength of cement-based material is very low at early-age and the friction can not be eliminated absolutely.
2 Detachable side panel and end plate can allow specimen to dilate in all orientations freely, when temperature vary. Thus a true linear TDC in length can be determined. Detachable side panel and end plate also help to increase the heating velocity, so a rapid even temperature shift can be produced in the specimen interior.
3 Because the block sheaves has the same displacement with the specimen end, the smooth ectotheca of the block sheaves can be used as the measurement contact. Thus the complicate deign of measurement contact can be avoided.

5 INTRODUCTION OF EXPERIMENT PURPOSE AND EXPERIMENT CURVES

Three series experiments are planed to do with pure cement, mortar and concrete. The pure cement is the basal composition of the cement-based materials, and is also the most active factor, which will result in a physical volume change. Studying TDC of the pure cement is a foundation to research the TDC of other the cement-based materials. The result of the experiment of the mortar and concrete can be used for the further mechanism analysis, on the other hand can be used for the actual usage directly.

Because the influence of temperature upon TDC is very complicate, the following temperature curves, from simple one to complicate one, will be used in the test. The first is the "interrupt rectangle wave curve" –the interrupt rectangle wave is superimposed on the isothermal temperature, see Figure 3. This temperature curve can let specimen have enough time to develop deformation and interior temperature. This temperature history is used to

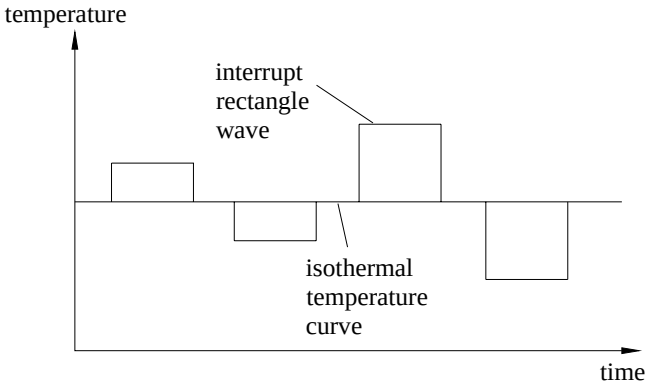

Figure 3. Interrupt rectangle wave curve

research the variation of the specimen' s interior temperature when the temperature of baking box changed and to make sure the time when the even temperature of specimen reached. The full development of transform can be used to research the occurrence time and magnitude of "delayed deformation" which is produced by temperature change. And in the test, the magnitude of temperature change and the value of isothermal temperature can be varied too.

The second is the "continue rectangle wave curve"-a continue rectangle wave is superimposed on isothermal temperature, the magnitude of rectangular wave can vary according to the need, see Figure 4. The test purpose is to measure the development of TDC of cement-based material in nearly isothermal temperature. The results of the experiment can be used in the stress calculation of plate.

The third is the "actual rectangle wave curve" – the rectangle wave is superimposed on the actual temperature history curve, which occurs in the cement-based material of big volume. The change forms of rectangle wave adopt monotonous rising and monotonous dropping, see Figure 5. The experiment purpose is to measure the development of TDC of cement-based material in nearly actual temperature history.

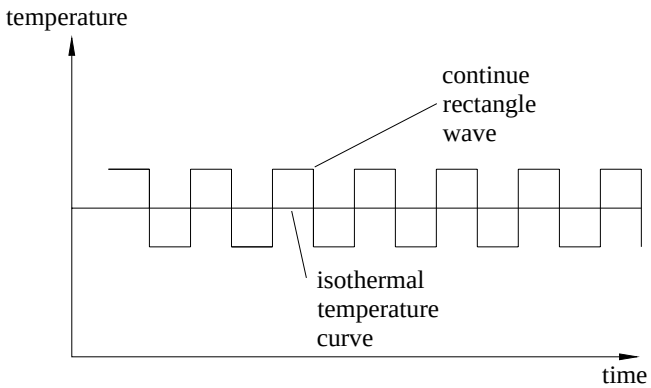

Figure 4. Continue rectangle wave curve.

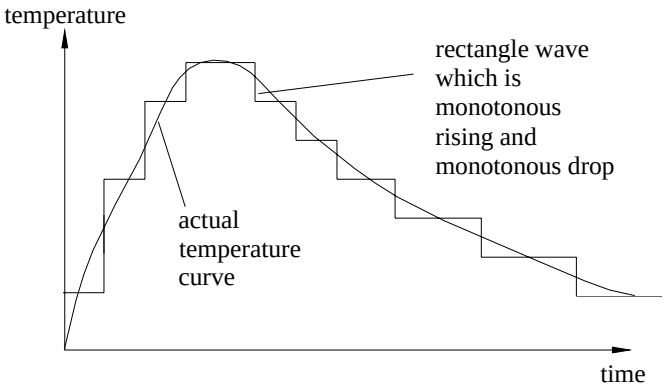

Figure 5. Actual rectangle wave curve.

6 CONCLUSION

The experiment of measuring the TDC of cement-based materials at early-age have a lot of difficulties in many respects. The principle of measuring methods is still not mature. Any new method is only an attempt to do certain improvement in some aspects. The Method putted forward in this paper has done some improvement in following aspects such as the accuracy of transform measuring, the controlling of the exterior temperature etc, but still exist many aspects that need to be improved.

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