Effect of Device Stiffness on the Evaluation of Early-age Creep in a Restraint Test

The University of Tokyo Student member Zhihai Lin
The University of Tokyo Formal member Toshiharu Kishi

1. Introduction

To accurately predict the stress evolution of young concrete is still a challenging question. The difficulty is mainly concentrated on the following aspects: temperature evolution, thermal deformation, autogenous shrinkage, early-age modulus, creep, etc. Among these aspects, early-age creep, which is also known as early-age stress relaxation, is a very complicated phenomenon.

Even now, how to accurately measure and quantify early-age creep is still uncertain. The most accepted method has been that early-age creep may be evaluated by the gap between the cumulative restored displacement, which is derived from a uniaxial restrained test, and the free shrinkage [1]. This method has been adopted in the researches in which the uniaxial restraint device was utilized.

However, the analysis of the testing process of the unixial restraint device shows that the stiffness of the device has a certain effect on the evaluated results of early-age creep, and the test results from different reports cannot be compared. In this paper, the effect of device stiffness will be pointed out.

2. Current evaluating method

To evaluate the early-age creep, a uniaxial restraint device is necessary. An illustration is shown in Figure 1. Three critical characteristics of this kind of device are a supporting steel frame which is fixed with a cross-head, an adjustable cross-head connected to a load cell, and a cyber-controlled activator system. The activator system is used to control the longitudinal position of the adjustable cross-head and therefore the length of the specimen is controllable.

During a test, the specimen tends to deform due to effects such as thermal deformation, autogenous shrinkage, and artificial expansion if the expansive additive is added. A full restraint degree can be achieved by restoring the specimen length back to the original value whenever its deformation exceeds a tiny threshold value like ±0.5μm. After the test, many restoration cycles can be observed, and can be assembled as a smooth curve of cumulative restored displacement.

The proposed evaluation method on early-age creep is quantified by the gap between the cumulative restored displacement obtained from a full restraint test and the free deformation. The illustration is shown in Figure 2. It should be noticed that in this method the effect of the stiffness of the device is neglected.

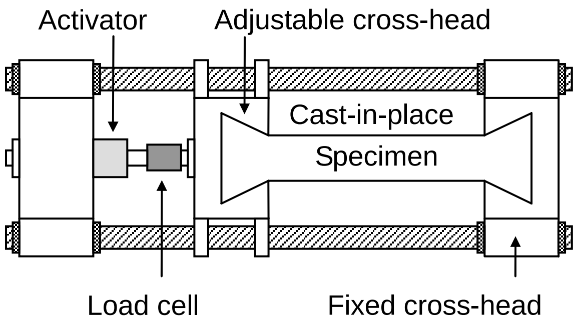

Fig.1 Illustration of uniaxial restrained device [2]

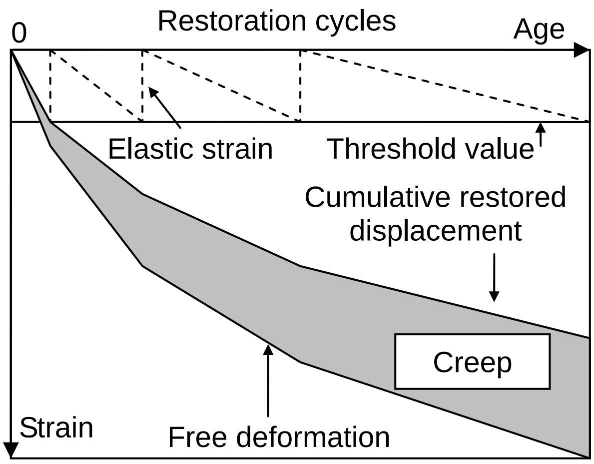

Fig.2 Creep strain calculated from the data of restrained and free shrinkage tests [1]

3. Analysis of the effect of device's stiffness

Whether the effect of the stiffness of the uniaxial restraint device on the evaluation of early-age creep can be neglected or not becomes a question, as results from different reports on similar test objects show large differences [3-4]. To investigate this question, modeling of the uniaxial restraint test is necessary to understand the essential meaning of cumulative restored displacement and the effect of device stiffness.

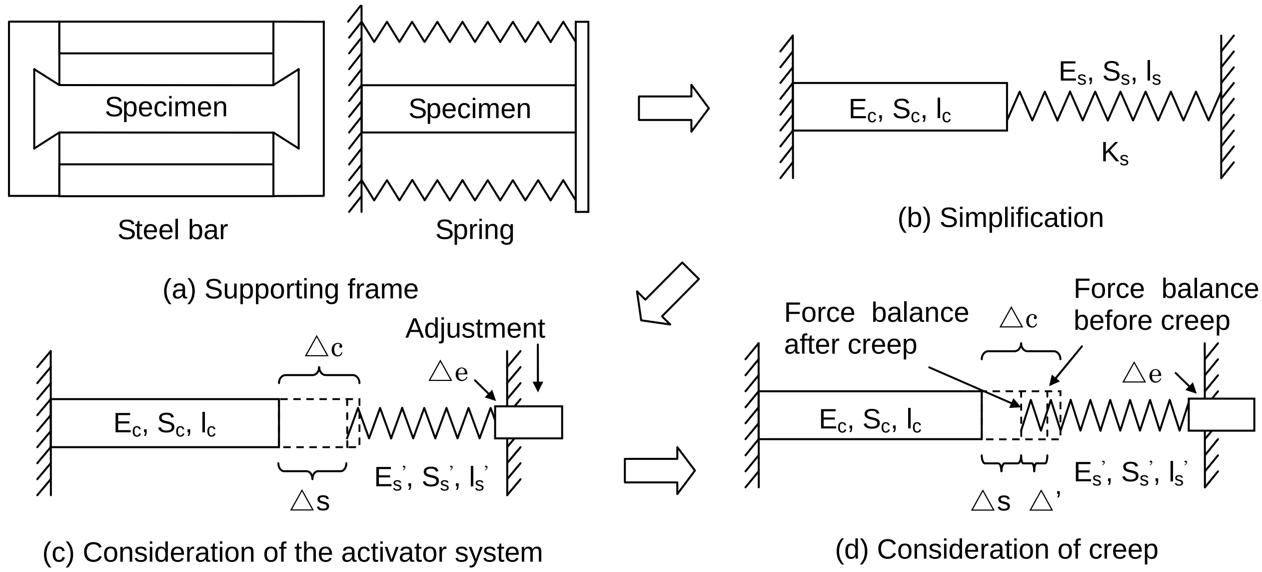

Fig.3 Modeling process of uniaxial restraint test

The modeling process is shown in Figure 3. In step (a), the bars of the supporting frame without activator system are replaced by two springs. In step (b), the springs are further combined into one. The spring constant of K_s is determined by the modulus E_s, cross-section area S_s and length l_s of the steel bars. In step (c), considering the stiffness of the activator system, the parameters of the spring are changed into E_s', S_s', l_s', and an infinite stiff adjustment is added, whose movement △e represents the deformation of the activator system. The specimen's free deformation is △c, and its elastic strain after overcoming the resistance of the spring is △s. △s is also a t deforming tendency which needs to always be counteracted by the activator system to achieve a full restraint degree. It cannot be directly observed but can be assembled by cumulating all the restored displacement. In step (d), the stress induced by the confinement of the spring causes creep △'. According to the force balance before the creep occurs, creep △' is given as follow:

$$\Delta' = \Delta c - \Delta s - \frac{\Delta c + \Delta e}{1 + \dfrac{E_c S_c l_s'}{E_s' S_s' l_c}} = \Delta c - \Delta s - k(\Delta c + \Delta e)\ ,\quad k = \frac{1}{1 + \dfrac{E_c S_c l_s'}{E_s' S_s' l_c}} \qquad (1)$$

It can be seen that except for the free deformation △c and cumulative restored displacement △s, the creep is also determined by the deformation of the activator system and the stiffness ratio of the specimen and device.

4. Conclusion

The effect of device's stiffness on evaluation of early-age creep cannot be neglected and is given in Eq. 1.

Reference

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