Research on measurement technology of cement bend resistant and compressive machine

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Abstract. To study the influence of nano material microscopic structure on the macro-mechanical properties of concrete, using AE test and numerical simulation methods, the AE characteristic of Nano-concrete under cyclic loading was investigated. The results show that the Nano-concrete has Kaiser effect, however, it occurs in a certain stress level range. Compared with ordinary concrete, the Nano-concrete has higher AE energy, larger AE amplitude and stronger AE activity during the first 3 loading processes due to the micro influence of Nano-SiO2. Nevertheless, in the 4th loading, the AE energy cumulative curve of Nano-concrete is relatively flat because of the improvement of the bearing capacity of Nano-concrete. The numerical simulation results of RFPA and experimental results are consistent. The stress diagram and AE figure are able to image the characteristics of the specimen crack propagation process and the rupture position, which helps an in-depth understanding on the AE characteristics of Nano-concrete during its damage process.

Keywords: Nano-concrete, acoustic emission, Kaiser effect, RFPA, numerical simulation.

1. Introduction
Cement concrete strength parameter, which is the key index for design and acceptance of engineering structure, is measured by laboratory. The measuring performance of cement concrete strength measuring instrument, i.e., cement flexural and compressive integrated machine, is the key to the accuracy of cement concrete strength data, so it is necessary to verify the measuring parameters of cement flexural and compressive integrated machine. One of the key measurement parameters, the loading speed of the cement bending and compression machine, has a great influence on the strength parameters of cement concrete. The change of loading speed of the cement bending and compression machine is a change process of dynamic force loading, and the verification of dynamic force is crucial to the measurement performance of the whole machine.

Fang Ling [1] measured the compressive strength and flexural strength of concrete in the construction process of a project, and obtained the correlation between compressive strength and flexural strength of ordinary concrete by using mathematical statistics and other related methods. Wu Bing [2] measured the flexural strength and compressive strength of cement mortar test blocks aged from 1 to 28 days, and conducted regression analysis under the least square criterion. The regression coefficient obtained by regression model can accurately judge the relationship between flexural

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strength and compressive strength of cement mortar test blocks. Hanxiao Zhang [3] applied dynamic mechanical analysis (DMA) to evaluate the adhesion between cement emulsified asphalt mortar (CEAM) and aggregate. The results showed that the viscosity of CEAM increased with the increase of cement content, mixing time and temperature. Cement content has the greatest influence on the viscosity of CEAM, followed by mixing time and temperature.

J P Hessling of SP discusses the range of dynamic measurement error from several aspects such as delay error, response error limit, asymptotic effect, frequency band effect and spectral distribution function, and gives the estimation model and process method [4]. In 2009, starting from the dynamic measurement system model, the model estimation error was defined. Based on the dynamic measurement uncertainty, the error of excitation signal propagates through the dynamic measurement model, and the error of excitation signal through the dynamic measurement model also brings uncertainty. The range search and propagation of both are estimated by Monte Carlo method, and then synthesized [5]. In 2011, the law of diffusion and propagation of dynamic uncertainty was studied [6]. On the other hand, Eichstdt systematically expounds how to use Monte Carlo method effectively in dynamic measurement, including giving system transfer function, system error function, input probability distribution density function, uncertainty propagation relation, uncertainty synthesis and so on [7]. Most of the above researches focus on the traceability of the basic quantities of engineering mechanics and metrology, but there is little research on the dynamic mechanical calibration of composite parameters of traffic detection equipment.

2. Study on the correlation between flexural strength and compressive strength of cement mortar specimens

2.1. Preparation of raw materials and test pieces
In this paper, GBT 17671-1999 cement mortar strength test method (ISO method) is applied to make standard mortar specimens with standard cement mortar ratio under standard ambient temperature conditions, and the flexural and compressive tests are carried out with standard experimental equipment. In the test, concrete standard cube blocks with side length of 40 mm×40 mm×160 mm were selected, which were demoulded after standing for 1 d and placed in standard curing room for curing. The flexural and compressive results of cement mortar specimens are shown in Table 1.

| Maintenance age /d | 28 |
|-------------------|----|
| Compressive strength /MPa | .35 | .36 | .36 | .37 | .37 | .38 | .38 | .39 | .40 |
| Flexural strength /MPa | 5.26 | 5.42 | 5.59 | 5.05 | 5.09 | 5.60 | 5.65 | 5.06 | 4.45 |

2.2. Correlation between flexural and compressive strength of cement mortar
Isotropy of cement mortar specimens is an important property of physical and mechanical properties of cement mortar specimens. The flexural and compressive tests were carried out on 9 cement mortar specimens in 3 groups under the same preparation conditions with a curing age of 28 days. The flexural and compressive results of cement mortar specimens are shown in Table 1.
Through the data scatter diagram after linear fitting, it can be seen that there is obvious linear relationship between flexural strength and compressive strength of cement mortar specimens.

Looking at the residual diagram of the original data, it can be seen that the flexural strength and compressive strength of cement mortar specimens have a good correlation, and there is no gross error that needs to be eliminated. By calculating the linear correlation coefficient $R^2$, the flexural strength and compressive strength of cement mortar specimens show a significant linear relationship. The linear analysis of flexural strength and compressive strength of cement mortar specimens eliminates the influence of loading speed on the isotropy of cement mortar specimens, in order to prepare for the dynamic force calibration of cement electric flexural and compressive integrated machine.

**Fig. 1** Correlation of flexural and compressive strength of cement mortar

**Fig. 2** Residual chart of original data
3. Study on dynamic force calibration of cement bending and compression machine

3.1. Analysis of key parameters of dynamic force calibration
The loading speed of flexural index of cement mortar specimen is 50 N/s 5 N/s, and the compression loading speed is 2400 N/s 200 N/s. During the whole loading cycle of cement mortar specimen, the value of loading force should be within the increment range. Therefore, the form of loading amplitude curve is linear, and the slope fluctuates within the loading speed range, so as to ensure the accuracy of flexural and compressive strength.

3.2. Establishment of dynamic force calibration numerical model
The size of sample model is 40 mm×40 mm×160 mm, which is divided into several grid elements and adopts three-dimensional stress problem. Considering the uniformity of cement mortar material, the model is solid homogeneous, and the mechanical parameters of the calculation model are shown in Table 2. The method of single loading is adopted.

| Loading property       | Elastic modulus/MPa | Loading speed MPa/s | Poisson's ratio | Density kg/m³ |
|------------------------|---------------------|---------------------|-----------------|---------------|
| Flexural resistance    | 20000               | 0.117±0.0117        | 0.2             | 26            |
| Compression            | 20000               | 1.5±0.125           | 0.2             | 26            |

3.3. Analysis of numerical simulation results
Fig. 4 is a numerical simulation curve of stress of cement mortar specimen under flexural-compressive loading under the simulated actual verification program. It can be seen from fig. 4 that the cement mortar specimen is absolutely linear under the influence of load. In Figure 1, the correlation obtained by testing the actual mortar specimen with the cement bending and compression machine is not as good as the theoretical linear correlation, which excludes the factors that may influence this situation. It is determined that the loading speed is lower than or beyond the loading range, which leads to the influence of the bending and compression data results [8].
In the past, the time average value of the full threshold was used as the verification value of the loading speed of the cement bending and compression machine, but the instantaneous loading speed in the whole loading period could not be verified.

Looking at the residual diagram of the original data in Figure 5, it can be seen that the theoretical simulation numerical correlation between flexural strength and compressive strength of cement mortar specimens is good, and there is no gross error that needs to be eliminated.
Fig. 6 Displacement curve of bending compression extreme point under full threshold loading

As shown in Figure 6, the maximum displacement point and minimum displacement point of flexural-compressive strength of cement mortar specimen after stress loading are analyzed, and its deformation is always linear within the quantitative loading step.

Fig. 7 Stress curve of bending compression extreme point under full threshold loading
It is further verified that the cement flexural and compressive integrated machine loads the cement mortar specimen linearly, so the stress change of the cement mortar specimen after loading is judged, as shown in Figure 7.

4. Conclusion
Based on the flexural-compressive relationship of cement mortar specimens under single load and finite element numerical simulation, this paper studies the influence of loading speed on test results, further discusses the importance of dynamic force verification of cement flexural-compressive integrated machine, and draws the following conclusions:

(1) Cement mortar specimens are generally elastic by default. Through data processing on the results of flexural and compressive specimens, it is concluded that there is a linear relationship between flexural strength and compressive strength of cement mortar specimens. Further, it is concluded that the data results of strength of cement mortar specimens have a great relationship with loading speed. From the perspective of metrological verification, it is an important means to ensure the accuracy of data results.

(2) Through comparison, it can be concluded that the flexural strength and compressive strength of cement mortar specimens are absolutely linear, and the stress limit points of cement mortar specimens are linear. Compared with the properties of solid specimens, the main factor causing the difference is the uneven change of loading force.

(3) From the point of view of metrological verification, it is important and necessary to verify the loading speed of the cement bending and compression machine. As the necessary equipment in the field laboratory, the accuracy of the verification results is related to the safety of engineering production.

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