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The Experimental Research of low strength Concrete Considering Strain Rate under Uniaxial Compression

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Abstract

The tests were implemented in low strength concrete with four kinds of strength (C20，C25，C30，C35) and with diffrent strain ratses ($10^{-5/s-1}$， $10^{-4/s-1}$， $10^{-3/s-1}$ and $10^{-2/s-1}$). The stress-strain curves, strength, elastic modulus and Poisson's ratio are studied in different strain rate. The results show that: (1) With the increase of strain rate, the inflexion strength and ultimate strength of concrete were improved; (2) With the increase of strain rate, the static and dynamic elastic modulus increased slightly; (3) Poisson's ratio increased slightly with the growth strain rate. This conclusion is very important in civil engineering.

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Keywords: concrete; strain rate; civil engineering; uniaxial compression

1. Introduction

The strain rate of concrete structures may be changed dramatically (from 10-8 / s to 103 / s), as shown in Figure 1.

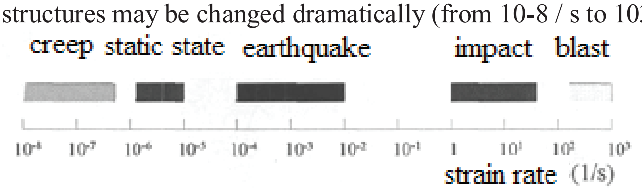

Fig.1 The changes of concrete strain rate in different kinds of loads

Because of the rate-sensitive of concrete, the strength, stiffness and ductility (or brittleness) of concrete structure should be affected by the loading rate. Obviously, there will be large errors to calculate concrete by static mechanical parameters. But now, in seismic calculation of concrete structure, the dynamic parameters obtained only

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by the static mechanical parameters of concrete (such as strength, elastic modulus) that increased a certain percentage.

Since 1917, Abrams [1] first found that the dynamic compressive strength of concrete depended on strain rate sensitivity. Bischoff [2] DM and Pavlovic (2007) [3] gathered the research results about concrete compressive properties affected by loading rate, such as fracture properties of concrete, strength, elastic modulus, critical strain and Poisson's ratio. Malvar [4] [5] summarized the research results about uniaxial tensile properties of concrete affected by loading rate. The dynamic loading test was complex than the static loading test, so the different test results in the existing experimental research were occurred because of different test techniques, such as test equipment, test methods, specimen age and failure characteristics of the impact. The accurate, systematic study is very necessary.

2. Test Overview

2.1. *Strain rates*

There were four kinds of strain rate ($10^{-5/s-1}$,$10^{-4\,/\,s-1}$,$10^{-3\,/\,s-1}$,$10^{-2\,/\,s-1}$)in the loading tests.

2.2. *Test specimens and materials*

About 84 specimens with four kinds of concrete strength inculding C20, C25, C30 and C35 were involved with a same size of 100mm × 100mm × 300mm. The actual strengths are shown in Table1.

Table1 Compressive strengths of concrete (Mpa)

strength grades	28d	60d	90d	180d
C20	21.78	23.76	29.93	28.14
C25	20.34	25.95	25.78	31.84
C30	28.01	38.79	38.69	42.79
C35	39.35	47.66	45.40	56.13

2.3. *Load and collecting device*

By the U.S. MTS hydraulic servo loading system with 500kN’s maximum output, the loading rate can meet the requirement of experiment. The relation between MTS load displacement and strain rate are shown in Table 2. For improve the testing machine stiffness obtaining a steady decline curve, the disc springs with bearing capacity, combined flexible and variable stiffness properties were used as an additional major components, as shown in Figure 2.

Srain of specimens were measured by resistance strain gauges whose sizeis 50 × 50mm. Meanwhile, for accurating to survey the post-deformation in the event of cracking, the high accuracy LVDT displacement sensor were used with standard distance of 100mm. Data acquisition equipment in these tests were Strainbook/616 dynamic acquisition system with 16 channels, maximum sampling frequency of 1MHz.

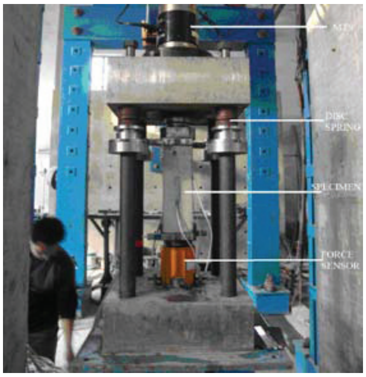


Fig.2 Devices of test

Table1 MTS displacement and strain rate

MTS displacement	Strain rate
8mm/600s	10^{-5}
8mm/60s	10^{-4}
8mm/6s	10^{-3}
8mm/0.6s	10^{-2}

3. Experimental results

3.1. peak strain

There was an increasing, but very little change to the peak strain of concrete in different strain rate. The trends were shown in Fig. 3.

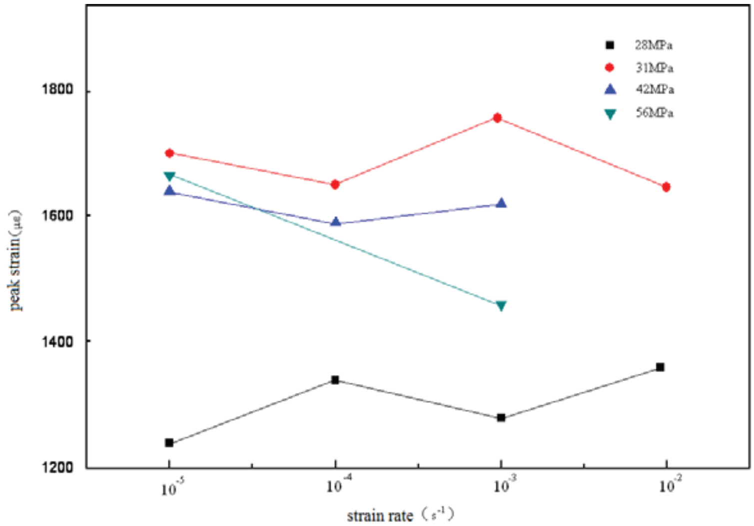


Fig.3 Peak strain of tests

3.2. Compressive strength of concrete

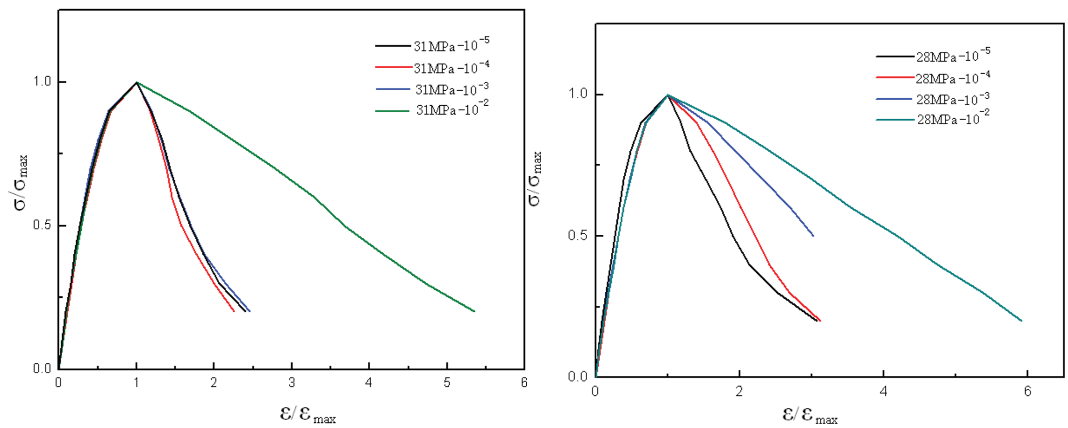
Experimental data is shown in Figure 13, as the strain rate increases, concrete ultimate compressive strength is growth. The relationship between increased rate of concrete strength and strain rate can be described with the following equation:

$$f_c / f_{cs} = 1 + \alpha \lg(\dot{\varepsilon}_c / \dot{\varepsilon}_{cs}) \quad (1)$$

f_c —Ultimate compressive strength under the current strain rate.
f_{cs}—Compressive strength in quasi-static strain rate.
$\dot{\varepsilon}_c$—The current strain rate.
$\dot{\varepsilon}_{cs}$—Quasi-static strain rate.
α —Material parameters coming from Test data, C20： α =0.105；C25: α =0.082；C30： α =0.066.

3.3. *The stress-strain curves*

Figure 4 showed the stress-strain curves of 28Mpa and 31Mpa in different strain rate (10^{-2}~10^{-5}). From the graph, the beginning of the stress-strain curve was similar in different strain rate, but after the turning point, there was a reduction in higher strain rate. The dynamic bearing capacity of the specimen was slightly higher than the static one.



(a) (b)

Fig.4 Stress–strain curves for concrete

3.4. *Elastic Modulus*

It can be seen from Figure 5, with the increasing of strain rate, elastic modulus will increase.

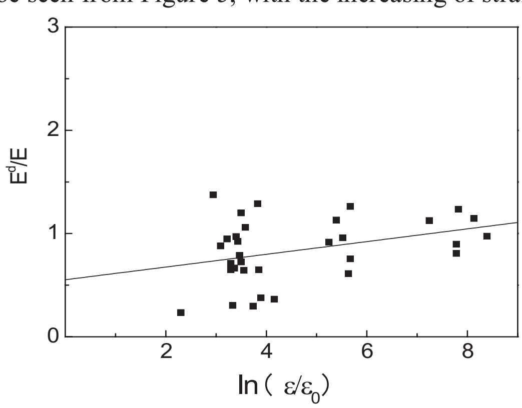


Fig.5 Young's modulus ratio

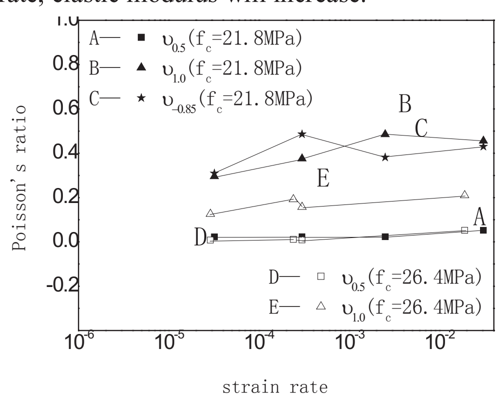


Fig.6 Poisson's ratio

3.5. *Poisson ratio*

As the strain rate increases, the Poisson ratio was showed an increasing trend in Figure 6.

4. Conclusion

The compressive strength of concrete is increased as the strain rate increases, and the growth range is from 3% to 30 %.

With the increase of strain rate, the peak strain of concrete is increased, but the changes are smaller than compressive strength (about 3% to 13.6%).

As the strain rate increases, elasticity modulus of four kinds of concrete are also showed growth trends, numerically from 5% to 15%.

Acknowledgements

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