Review on fatigue behavior of high-strength concrete after high temperature

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Abstract. The fatigue of high-strength concrete after high temperature has begun to attract attention. But so far the researches work about the fatigue of high-strength concrete after high temperature have not been reported. This article based on a large number of literature. The research work about the fatigue of high-strength concrete after high temperature are reviewed, analysed and expected, which can provide some reference for the experimental study of fatigue damage analysis.

1. Introduction
In practice, HSC structures not only need to withstand static load, but also have to bear cyclic loads such as vehicle, wind, wave or others, and sometimes even suffer a fire or other high temperature history, which will cause fatigue damage. At present, the research on the fatigue properties of HSC after high temperature has become a central issue for scholars.

So far, there are many researches on high-strength concrete, but most researches [1-3] mainly focus on the basic properties of HSC, such as strength and durability. The studies on the fatigue damage of concrete after high temperature are few and only focus on axial compression fatigue of plain concrete after high temperature [4]. While, fatigue properties of HSC after high temperature have not been reported. In this paper, the research on the fatigue properties of HSC after high temperature is reviewed, analyzed and evaluated. It can provide reference for fatigue test and damage analysis of HSC after high temperature.

2. Research status of fatigue behaviour of HSC
Wu Peigang et al [5] studied the axial compression fatigue behavior of HSC under constant-amplitude and variable-amplitude repeated loads. Based on the tests, fatigue strength and fatigue deformation of HSC under constant-amplitude repeated loading were analyzed, the empirical formula of longitudinal total strain and residual strain of fatigue strength were given, and a formula for judging the fatigue failure by residual strain was put forward. Lu Xiaobin et al [3] pointed out that HSC with lateral confining pressure growth, the axial peak strain $\varepsilon_{1c}$ and transverse peak strain $\varepsilon_{3c}$ also significantly increased, and in the triaxial compression of different loading path seemed to limit strength $\sigma_{1c}$ and $\sigma_{3c}$ curve of the status quo was minimal. Tian Yaogang et al [6] studied the introduction of the damper of concrete under the vibration load of bending fatigue performance. Compared with the same level of strength of HSC, the anti-fatigue performance of HSC with damping function was obviously improved. With the increase of vibration fatigue load, the service life of HSC with damping function was obviously reduced. On the basis of experiment, the vibration fatigue life...
prediction equation of HSC with damping function under different failure probabilities was established. He Zhenjun et al [7] conducted a high-strength high-performance concrete at different stress ratio of multi-axis tension and compression tests, which showed that the compressive strength and deformation of multi-axial tension and compression depend on the stress state and stress ratio, and the multi-axial tensile strength $\sigma_{1f}$ and $\sigma_{3f}$ were smaller than the uniaxial tensile and compressive strength $f_t$ and $f_c$ at all stress ratios. And the peak strain $\varepsilon_{3p}$ of the main pressure was the largest in uniaxial compression.

A dynamic triaxial compression test of HSC was carried out by JKGran et al [8]. It pointed that stress-strain relationships, stress and strain measurements in triaxle compression, which provided data and a reference for the complete nonlinear relationship between stress and strain tensors. Ertekin Aztecan et al [9] performed the Drucker-Prager yield criterion for triaxle compression tests of ordinary and HSC. The Drucker-Prager parameter value increased with the increase of the ordinary concrete strength, and the Drucker-Prager parameter equation and the correctness of the equation were proved by the data collected.

3. Research status of mechanical properties of HSC after high temperature
Li Lijuan et al [10] conducted a high-temperature test on HSC (100 MPa), which studied its appearance, compressive strength, flexural strength and splitting tensile strength after 500$^\circ$C and 800$^\circ$C. HSC after high temperature could occur bursting phenomenon, with the fire temperature increasing, compressive strength, flexural strength and tensile strength splitting gradually become smaller, microstructure gradually worse. Mainly as follows: the loss of crystal water, cement hydrate decomposition occurs when the fire temperature reaches 800$^\circ$C, the crystal water all lost, cement hydrate all the decomposition, the structure becomes loose. He Zhenjun [11-12] conducted C50 and C60 of HSC under multi-axial stress state strength and deformation performance test after high temperature. And the corresponding failure modes and mechanisms, multiaxial strength, peak strain, stress-strain curves of the specimens under different stress states and different stress ratios after different high temperatures were analyzed, and the corresponding strength and deformation conclusions were given. The failure criterion formula of HSC under multi-axial stress condition was established. Zhao Dongfu et al [13] studied the microstructural changes of HSC after different temperature and different constant temperature time from different angles by means of ultrasonic, scanning electron microscopy, X-ray diffraction and so on. The physical and chemical changes and the resulting microstructure changes were analyzed, studies had shown that with the heating temperature and constant temperature time, the compressive strength of concrete showed a trend of decreasing.

Long T et al [14] studied the fire performance of HSC and compiled the fire test data. It indicated that HSC and plain concrete showed great difference in the temperature range of 20$^\circ$C to 400$^\circ$C. Fu-Ping Cheng et al [15] studied the stress-strain curves of high-strength concrete at 20$^\circ$C, 100$^\circ$C, 200$^\circ$C, 400$^\circ$C, 600$^\circ$C and 800$^\circ$C, and pointed out that the compressive strength of HSC increased with temperature. The compressive strength at 800$^\circ$C was about one quarter of its initial strength. Masood Ghandehari et al [16] tested compressive strength, splitting tensile strength and corresponding ultrasonic pulse velocity of high-strength concrete after 100$^\circ$C, 200$^\circ$C, 300$^\circ$C and 600$^\circ$C. It was found that with the increase of temperature, HSC was higher than the compressive strength loss rate and the residual strength measured at the ultrasonic pulse velocity was slightly lower than the value directly exposed to more than 200$^\circ$C.

4. Conclusions and outlook
By summarizing and analysing the research on the fatigue properties of HSC after high temperature in recent years. It is found that there are many researches focused on the mechanical properties but little research focused on the fatigue properties. What’s more, many researchers considered the fatigue, complex environment and other factors separately, which made those studies don’t meet the objective engineering practice well and can’t correctly determine the damage process and extent of HSC.
Because of different research purposes and angles, the studies on the fatigue of HSC after high temperature didn’t connect the temperature history well with macro-mechanical properties, and cannot reveal its evolution mechanism under high temperature and complex load. The relationships between temperature, length of time and macro-mechanical properties of HSC have not been established yet. The research needs to be studied further and more systemic, which will be the main direction to study the fatigue performance of HSC.

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