Review on self-compacting concrete creep

Wang Hui1,a and Wang Yue1*

1School of Civil Engineering, North China University of Technology, 100144, Beijing, China
2wanghui@ncut.edu.cn
3Corresponding author’s e-mail: dqzgsxslng@163.com

Abstract: Creep is a phenomenon that the deformation of concrete structure increases with time under continuous load. This paper reviews the research results of concrete creep performance at home and abroad, introduces the self-compacting concrete creep, and the future work is proposed.

1. Introduction

As an important characteristic of concrete, creep can last for a long time. It developed rapidly in the early stage and slowed down with the increase of age. It affects the durability and safety of concrete structure, and is an important factor that cannot be ignored in structural design. In the prestressed concrete structure, creep can cause the loss of prestress; in the long-span beam, the creep will increase the deflection of the beam, which is unfavorable to the structure. However, creep has a positive effect on the early shrinkage cracking of concrete. In the early stage, creep can reduce the tensile stress caused by temperature and shrinkage deformation in the concrete, so as to alleviate the generation and development of internal cracks in concrete. Therefore, it is very important to consider the creep of concrete reasonably.

2. Research on concrete creep

Since the discovery of concrete creep in the 20th century[1], a large number of experts and scholars have carried out in-depth research, accumulated a large number of practical value of experimental research data, concrete creep research has made great achievements. Creep refers to the phenomenon that the deformation of concrete increases with time under long-term load. Under the action of long-term load, the creep deformation of concrete cannot be underestimated, it continues to occur in the whole service life cycle of the building[2].

2.1. Mechanism and influencing factors of concrete creep

Experts and scholars at home and abroad have put forward various theories to explain the creep mechanism. It is believed that concrete creep is related to the migration of gel and water in concrete, the delayed elastic deformation of aggregates, and the propagation of micro cracks in concrete, but there is no unified cognition. There are many theories to explain the creep mechanism of concrete, which are generally based on the microstructure of cement paste. At present, there are mainly seepage theory, viscous flow theory, plastic flow theory, internal force balance theory and micro crack theory[3]. These theories are difficult to explain the creep mechanism of concrete completely and reasonably. Many hypotheses have been put forward by scholars of various countries, such as kesler hypothesis,
ruetz hypothesis, cilosani hypothesis, Feldman & Sereda hypothesis and ishai hypothesis. A large number of studies show that the factors affecting concrete creep include raw materials, mix proportion, ambient temperature, environmental humidity, specimen size, loading process and so on.

The main influence of cement on concrete creep is its influence on concrete strength. In the case of early age loading, concrete creep increases in the order of fast hardening cement, ordinary cement and low heat cement. If the cement strength is high, the creep of concrete is small. The experimental study of Kangvapanich[4] shows that under the same other conditions, the higher the substitution ratio is, the greater the concrete creep is, and the trend is consistent with the change trend of concrete compressive strength. The finer the cement particles, the higher the early strength, the faster the strength development and the smaller the creep.

The creep of the aggregate itself is very small. The existence of aggregate can restrain and absorb water to cement paste, so the creep deformation of concrete will be reduced by using aggregates with strong deformation restraint ability. Generally, the porosity of aggregate is large, and its elastic modulus is low. When the elastic modulus of aggregate is greater than 6×10^4/Mpa, the influence of aggregate on concrete creep is very small. Troxell's research shows that the creep of different rock aggregate concrete is quite different. Under the premise of other fixed conditions, the creep of sandstone aggregate concrete with the minimum elastic modulus is 2.3 times and 5 times of that of limestone aggregate concrete with the largest elastic modulus.

The main material causing concrete creep is cement paste, so the main factor affecting concrete creep is water cement ratio. The larger the water cement ratio of concrete is, the larger the spacing of cement particles, the more pores and the larger the capillary pore diameter, the larger the creep will be.

When curing concrete, the environmental temperature and humidity will affect the development of concrete strength. For concrete, the lower the relative humidity, the greater the creep. With the increase of temperature, the viscosity and elastic modulus of concrete will decrease, and the creep of concrete increase.

Some studies show that when the volume surface area ratio is greater than 0.9m, the influence of component size on concrete creep can be ignored[6]. Some other studies believe that The size effect of components will affect the creep deformation of concrete, that is to say, the larger the volume surface area ratio is, the smaller the creep deformation of concrete is[7].

2.2. Research on creep of concrete containing mineral admixtures

In order to meet the needs of practical projects, admixtures will be added when pouring concrete to improve the strength, increase the workability of concrete, improve the frost resistance, save cement or adjust the setting time. The effect of different admixtures on concrete creep is different.

Fly ash has great influence on concrete creep. The early strength of concrete with fly ash is lower than that of concrete without fly ash, and the later strength of concrete with fly ash is higher than that without fly ash. Therefore, the concrete creep of early age loading is larger than that of late age. In the early age, the creep of concrete with fly ash will increase with the increase of fly ash content. Under the same strength condition, the creep of concrete with fly ash is smaller than that without fly ash[8]. Fly ash is one of the most widely used mineral admixtures, and there are many experimental data to study the effect of fly ash on concrete creep. Zhao Qingxin's[9] experiment shows that the creep shrinkage of concrete is smaller than that of pure cement concrete when the replacement ratio of fly ash is 12% and 30%. When the replacement ratio is increased to 50%, the creep reduction of concrete decreases, which is 1.02 times of that of the group without fly ash.

Huang Haisheng[10] and others studied the influence of fly ash and mineral powder on the creep performance of recycled concrete. The total creep degree of recycled concrete is larger than that of ordinary concrete. The total creep and basic creep of recycled concrete can be effectively reduced by adding appropriate amount of fly ash or fly ash with mineral powder.

Zhang rongling[11] studied the influence of the amount of expansive agent on the creep performance of concrete filled steel tube, and carried out the creep test of concrete filled steel tube with the content
of 4%, 8% and 12% respectively. The results show that the creep decreases with the increase of the content of expansive agent.

2.3. Research on creep of self-compacting concrete

Self-compacting concrete is a kind of concrete with high fluidity under low water binder ratio, which does not segregate and bleed in the process of pouring, and can fill the formwork and wrap the reinforcement without vibration. Because of its good workability and mechanical properties, it has been widely used in various projects. The mix proportion of self-compacting concrete is different from that of ordinary concrete, and its creep performance is different from that of ordinary concrete.

Yan Peiyu [12] studied the creep and shrinkage characteristics of high-strength self-compacting concrete and ordinary concrete. The research shows that the creep degree of concrete decreases with the increase of its strength grade, and the creep degree of self-compacting concrete with the same strength grade is larger than that of ordinary concrete. The difference increases with the increase of concrete age and strength grade, and the difference also increases slightly.

The experimental study of Zhang Yunguo [13] shows that the creep of self-compacting concrete with lightweight aggregate is larger than that of self-compacting concrete with ordinary aggregate.

Luo surong [14] conducted tension and compression creep tests of self-compacting concrete in open state and sealed state respectively. The results of the two states show that the tensile creep of self-compacting concrete is slightly less than that of compression creep. The basic creep ratio increases slightly with the increase of fly ash content, and the ratio of tensile creep and compressive creep decreases with the increase of curing age, water binder ratio and fly ash.

Chao Pengfei [15] conducted creep loading tests on 28 open and 28 sealed specimens of self-compacting concrete and ordinary concrete. The results show that with the decrease of water binder ratio, the creep degree of self-compacting concrete decreases; the total creep of self-compacting concrete increases faster than that of ordinary concrete at early stage, and decreases gradually with the increase of age, which is lower than that of ordinary concrete.

2.4. Research on creep of concrete with manufacture sand

Manufacture sand is a fine aggregate manufactured from rock or industrial waste residue particles, by processing, crushing and scrubbing materials. And the particles are finer than 4.75 mm. Differing from river sand, manufacture sand has special features such as rough surface, irregular particle shape, angular edges and distinguishing characteristics of stone powder contained [16], which has some special effects on the workability and durability of concrete.

Zheng Yi [17] carried out an experimental study on the shrinkage and creep properties of concrete with limestone manufacture sand. The research shows that the creep of concrete with limestone manufacture sand is much greater than that of concrete with river sand. They think that this is because there is a considerable proportion of limestone powder in limestone manufacture sand, which reacts with C3A to form hydrated calcium aluminate crystal, which increases the amount of hydration products. There are more pastes in concrete with limestone manufacture sand than that in ordinary concrete, so its creep is larger than that of concrete with river sand. The loading age also has a very important influence on the creep of concrete with limestone manufacture sand, because the creep decreases obviously with the increase of loading age.

Meng Yafeng [18] carried out the elastic modulus, dry shrinkage and creep tests of concrete with manufacture sand, and the results show that the creep degree of concrete with manufacture sand is lower than that of concrete with river sand. They think that manufacture sand will bring powder, increase the content of paste, improve the compactness of concrete, so as to improve the elastic modulus of concrete, reduce the dry shrinkage and creep.

The test results of Wang zhen [19] show that the creep coefficient of concrete with manufacture sand is consistent with that of concrete with river sand. Under the same conditions, manufacture sand can reduce the creep deformation of concrete because of its strong angularity and strong binding force on the deformation of paste. However, the stone powder in the manufacture sand will increase the volume
content of cement paste and improve the creep deformation of concrete with manufacture sand. When different factors occupy the main factor, the final creep deformation of concrete with manufacture sand may be different.

3. Conclusion
The factors affecting concrete creep are very complex, including internal factors such as cement, aggregate, mineral admixtures and external factors such as loading age, loading stress, temperature and humidity. According to the above research at home and abroad, it can be seen that different mineral admixtures have different effects on the creep performance of concrete, and the creep performance of concrete with manufacture sand and self-compacting concrete is also significantly different from that of ordinary concrete.

With the rapid development of China's infrastructure, more and more self-compacting concrete is used in engineering, and the demand for building sand materials is also increasing. Due to the limitation of natural resources, using manufacture sand to replace natural sand has become a development trend. The application of manufacture sand in self-compacting concrete can not only solve the problem of resource shortage, but also relieve the environmental pressure. At present, the application of self-compacting concrete with manufacture sand has been quite extensive. There are few researches on creep of self-compacting concrete with manufacture sand. Therefore, it is necessary to study the creep performance of self-compacting concrete with manufacture sand.

References
[1] Hatt, W.K. (1907) Effect of Time Element in Loading Concrete. ASTM Proceeding, 421.
[2] American Concrete Institute. (1994) Prediction of creep, shrinkage and temperature effects in concrete structure. Farmington Hills, Michigan: American Concrete Institute.
[3] Huang Guoxing, Hui Rongyan, Wang Xiujun. (2011) Creep and shrinkage of concrete. China Electric Power Press, Beijing.
[4] Kangvanpanich, K. (2002) Early age creep of self-compacting concrete using low heat cement at different Stress/Strength ratios. Kochi University of Technology.
[5] Bažant, Z.P. (2001) Prediction of concrete creep and shrinkage: past, present and future. Nuclear Engineering and Design, 203(1): 27-38.
[6] Neville, A.M., Dilger, W.H., Brooks, J.J. (1983) Creep of plain and structural concrete. Construction Press.
[7] Hansen, T.C., Mattock, A.H. (1966) Influence of Size and Shape of Member on the Shrinkage and Creep of Concrete. Portland Cement Association, Research and Development Laboratories.
[8] Zhang Jianbin, Wang Jun, Wu Kaiyun, et al. (2014) Study on the influence of different mineral admixtures on concrete properties. Commercial concrete, 3: 64-65.
[9] Zhao Qingxin, Sun Wei, Zheng Keren, et al. (2006) Effect of fly ash content on creep performance of high performance concrete and its mechanism. Acta silicate Sinica, 34 (4): 446-451.
[10] Huang Haisheng, Zheng Jianlan. (2017) Study on the influence of fly ash and mineral powder on the creep performance of recycled concrete. Journal of Fuzhou University (NATURAL SCIENCE EDITION), 2.
[11] Zhang Rongling, Wang Qicai, Ge Yong, et al. (2014) Influence of expansive agent content on creep behavior of concrete filled steel tube. Highway transportation science and technology, 31 (11): 66-71.
[12] Yan Peiyu, Zhou Zhikai, Liu Weiteng, et al. (2016) Study on creep characteristics of high strength self-compacting concrete. Industrial architecture, 46 (9).
[13] Zhang Yunguo, Wu Xi, Bi Qiaowei. (2014) Shrinkage and creep properties of self compacting lightweight aggregate concrete. Journal of materials science and engineering, 32 (1): 35-39.
[14] Luo surong, Chao Pengfei, Zheng Jianlan. (2012) Comparative experimental study on tension compression creep of self-compacting concrete. Engineering mechanics, 29 (12): 95-100.
[15] Chao Pengfei, Zheng Jianlan. (2010) Experimental study on creep behavior of self-compacting concrete. Journal of building structures, 2:103-107.
[16] Dong Rui, Chen Xiaofang, Zhong Jianfeng, et al. (2013) Study on characteristics of limestone manufacture sand. Highway transportation technology: Application Technology Edition, 12: 225-230.
[17] Zheng Yi, Zhang Yaoting. (2013) Experimental study on shrinkage and creep properties of limestone manufacture sand concrete. Acta civil engineering, 12: 69-75.
[18] Meng Yafeng, Xie Jianliang, Shen Weiguo, et al. (2019) Study on the adaptability of manufactured sand in concrete. Concrete, 5.
[19] Wang Zhen, Han Zili, Li Huajian, et al. (2019) Study on performance of manufacture sand concrete for prestressed structure of Railway Engineering. Railway architecture, 4.