Analysis of Properties and Influence Factors About Compressive Creep of Concrete

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Abstract. Creep is one of important objects in concrete studies. As the creep research progresses, the change of creep of concrete under different conditions becomes an important topic. Therefore, this study explores the variation trends on creep of concretes in various stress, time and temperature by data collection and contrastive analysis. Some important properties of compressive creep in concretes were obtained. To be more specific, if one of compressive stress, time and temperature grows or reduces in the stationary condition, the creep will increase or decreases correspondingly. In other words, the changes of creep in concretes are synchronous with the three factors, but the magnitudes of variation are different (non-linear). Therefore, the engineers and other workers can control the creep by rising the compressive load carrying capacity, regularly inspecting components, and avoiding fires. This study can provide valuable information and properties of compressive creep in concretes and help the designers easily use the right materials. Finally, the study offers some new topics that can be explored by other researches as targets.

Keywords: Concrete; compressive creep; stress; time; temperature.

1. Introduction

The creep of concretes is a popular topic in the material and construction studies. In the practical experiments, the creep is difficult to measure directly, which always takes a lot of time and efforts. For example, in the high temperature, the totally deformation includes elastic strain, plastic strain, cracking strain, transient creep, thermal strain and stain of shrinkage phenomenon [1]. It shows that the strain of concretes is complex. At present, measurement of creep mainly depends on two methods which are machine and mathematical model. Even though using mathematical models, the researchers also need to base on the existing experimental data. Therefore, the experiment of creep becomes more and more valuable. In addition, the creep of concrete has some inevitable and negative influences, which makes the study of creep more significant. For example, creep of concretes may decrease the resistance and service life of structure [2]. It can also affect the distribution of deflection and stress, which can reduce the bearing capacity of concrete and even damage it [3]. To prevent the adverse effects of creep in concretes, more and more researchers devote themselves to figure out the properties of creep.

This study focuses on three aspects of compression creep properties in terms of stress, time and temperature. For normal temperature, there is enough literature to prove the property of creep. But high temperature on creep in concrete is uncertain due to the limited number of tests conducted in this field [4]. Thus, the exploration of creep in high temperature is probed by digital models. For the time factor, most experiments of creep can show the exact data in short term and found that creep of concrete is dependent on time [5]. The situation of long-term creep is similar to the high temperature, which is limited and just explored by mathematical models. However, the data about stress-stain (creep) is vast in concretes. There are abundant arguments which can help the author to find the property of compressive creep in stress. But for this reason, most researches on the mechanical behavior of concretes are limited to compression stress and explorations of creep behavior, rather than tension [6]. This point needs to be corrected by the researchers who study creep in concretes.

This study explores the influence factors of concretes' compressive creep in stress, time and temperature based on existing data from experiments and mathematical models. Then the author uses contrastive analysis to obtain the information and summarize the corresponding properties and

variation trends. These conclusions have significant meaning for the concrete structures. Although there is still vacancy in the study such as transient creep, the author will study this domain in the future and provide more accurate data in the experiment.

2. Details of creep

2.1. Definition

One object is compressed or tensed by loads for a certain amount of time, then the object causes deformation which is creep. Since the concrete always bears compressive loads in the actual design, the author just focuses on the compressive creep of concrete to explore behaviors and properties of creep under different situations. In addition, creep causes a lot of effects in usage. If the engineering can grasp the properties of creep, there will be less danger and more safety in the building.

2.2. Effects

The effects of creep on buildings are variable. Some influence is negative, such as the Shear lag effect. Due to the shear lag effect, engineering may underestimate the deflection of box girder leading to an unstable structure. What's more, the creep can reinforce this effect to make building dangerous, referring to Figure 1. and Figure 2. [7]. In addition, creep can also cause fissures, which not only affects the safety of structures but also has a huge influence on appearance [8]. As time going, water enters the structure through these fissures and causes the corrosion of metals to generating more damage. Therefore, it is important to grasp and understand the properties of creep. Before studying the properties and behaviors, the influence factors are not negligible.

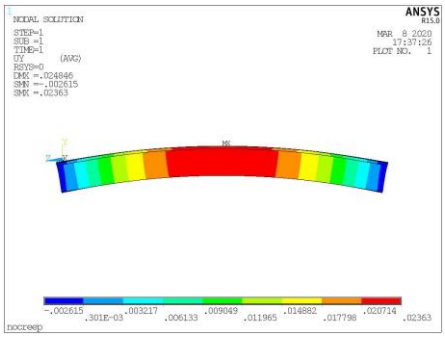


Fig. 1 Deflection of the beam [7]

Figure 1 shows original the deflection of the beam in the study, which includes no creep.

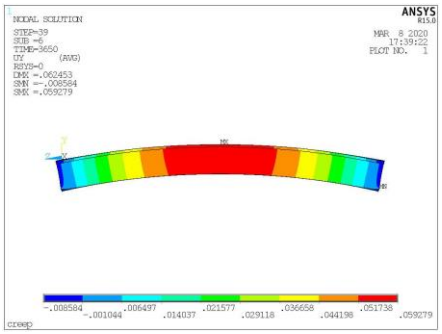


Fig. 2 Deflection of the beam with creep [7]

Figure 2 shows the deflection of the beam after producing creep in the study. Then the author will have contrastive analysis through Figure 1 and Figure 2.

2.3. Influence factors

Creep is influenced by many factors, which can be divided into two categories. The first is the internal factor, which is the material of concrete. The other is the external factor, which is a situation

of concrete. The external factors mainly include stress intensity, time, temperature, humidity and air content [9]. In this study, the author focusses on the external factor to study the properties and behaviors of compressive creep in concrete.

3. Influence of compressive stress on creep of concretes in quantity

3.1. Controlling variable

The author chose a part of the research in Université Paris-Est as the argument. The experimental study of compressive concrete was under three different stresses, which were 30%, 50% and 70% of the compressive strength of the concrete [10]. Throughout the research, two types of concretes were used and the difference between them is the age at loads. Because just one variable is allowed in analysis, the argument uses one of these concretes, whose age at loading is 145 days, the mix design as shown in Table 1[10]. Table 1 shows the information on concrete and the water-cement ratio can be calculated which is 0.5412 approximately. And this concrete is loaded in 50% and 70% stress levels, referring to Figure 3 and Figure 4 [10]. Then a lot of information can be obtained through these figures.

Table 1. Mix design of the chosen concrete [10]

Component	Unit: kg/m3
Cement: CEMI 52.5 N PMES CA2	340
Dried sand–lime aggregate 0/4	739
Dried sand–lime aggregate 6.3/20	1072
Added water	184

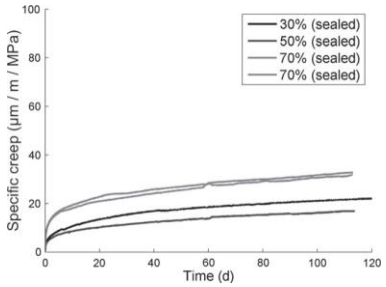


Fig. 3 Specific creep vs. time for sealed specimens [10]

Figure 3 shows how much creep the sealed concrete in research is deformed by 50% and 70% compressive stress. The lowest line represents 50% and two higher lines represent 70%. Two lines for 70% are in the same condition to check each other.

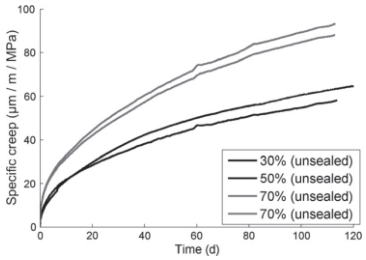


Fig. 4 Specific creep vs. time for unsealed specimens [10]

Figure 4 shows how much creep the unsealed concrete in research is deformed by 50% and 70% compressive stress. The lowest line represents 50% and two higher lines represent 70%. But two lines for 70% are different in creep duration at 120 days (a) and 440 days (b). And the latter is loaded for 34Mpa which is 1 MPa more than the former.

3.2. Analysis

Due to the control variable, just the lines for 50% and 70% need to be mentioned. Several properties are similar between Figure 3 and Figure 4. First, the creep of the concrete loaded at 70% compressive stress is always bigger than it loaded at 50%, which can obtain that when one kind of concretes in the same environment and time, the larger compressive stress, the bigger creep. In addition, in Figure 4, the creep of 70% (b) is more than the creep of 70% (a), which can prove the property again. Second, although the material is not in this study range, the property that the unsealed concretes have larger creep than sealed concretes through the comparison of the two figures. It is because the unsealed concrete absorbs more water in the air, which makes the concretes softer. Then they can be deformed more easily. Third, in the two figures, the lines of 70% stress are as approximately two times big as the lines of 50% stress. This relationship may be proved with a lot of data in future study. Just depending on one experiment, it is difficult to affirm. Finally, in Figure 3, two lines of 70% stress are same approximately, which is reasonable because of allowable error. It proves the experiment's accuracy in the further way. The author will explore more accurate data in the further study.

4. Influence of compressive stress on creep of concretes in time

4.1. Inverse analysis method

There are fewer measurement experiments for a long-time creep in concrete, the author uses a study of predicting by Inverse analysis method as the argument. This argument is from University of Pennsylvania. The inverse analysis method uses measurements of the short-term creep to model the changes of creep and obtain the creep coefficients [11]. The creep coefficient is the ratio of creep strain to elastic coefficient. In this study, the concrete is fixed, so the creep coefficients can show the same trends as a creep. And then use the software to minimize the difference between the experimental results and predicted values. Finally, use the creep coefficients to predict the long-term creep, referring to Figure 5 [11]. During the whole study, diverse models are used for results. But every concrete is loaded at the constant compressive stress and in the fixed environment to control variables. In the study from University of Pennsylvania, there are 6 models of the long-term creep coefficients. The author chooses 2 of them to have contrastive analysis, referring to Figure 6 and Figure 7 [11]. Figure 6 and Figure 7 show all models and data from two different concretes respectively.

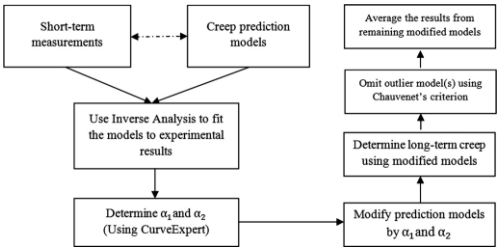


Fig. 5 Process of long-term creep prediction using short-term measurements [11]

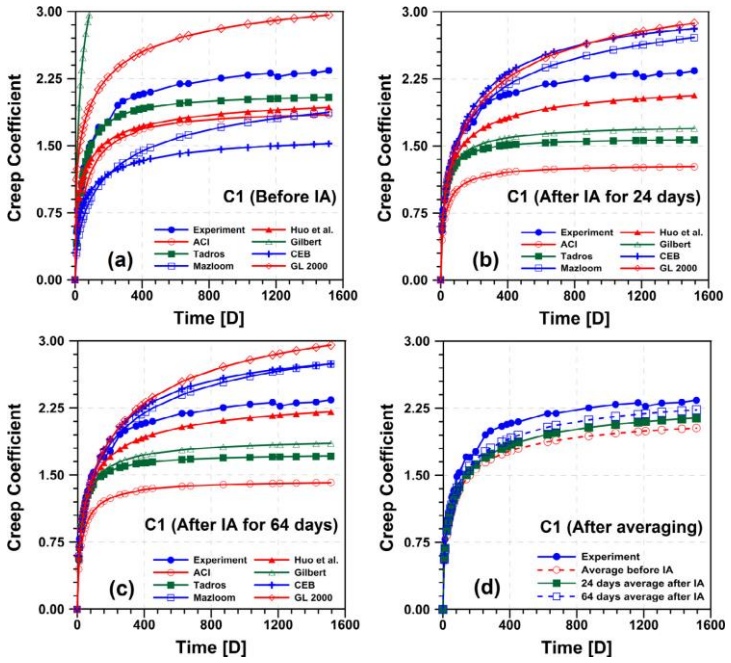


Fig. 6 Creep coefficient of C1: (a) before IA; (b) after IA for 24-day measurements; (c) after IA for 64-day measurements; and (d) after averaging [11]

Figure 6 shows the variation of the creep coefficient for specimen C1 in different terms.

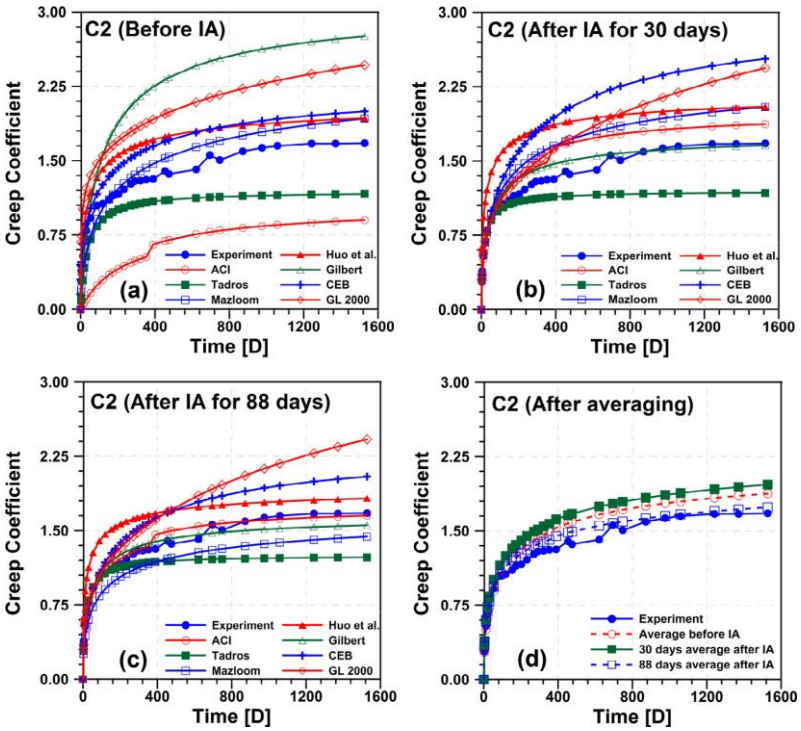


Fig. 7 Creep coefficient of C2: (a) before IA; (b) after IA for 30-day measurements; (c) after IA for 88-day measurements; (d) after averaging [11]

Figure 7 shows the variation of the creep coefficient for specimen C1 in different terms.

4.2. Analysis

Because these data were made by the researchers through IA (Inverse Analysis) to predict the long-term creep, the author analyzes the data by looking at only the last graph of each figure. In the two figures, it is easy to find that the data approximates a LOG function that approaches a straight line at the end. It can prove that the creep coefficient hardly changes at the end. Because only one sample is used in each study, the elasticity coefficient is the same in one study. Therefore, the creep increases

more and more slowly and approaches a constant during a long-term process. In addition, the slope of creep coefficients is from large too small. It proves that the creep grows rapidly at first, but the growth rate gradually slows down. In other words, the creep of concretes becomes large rapidly in short term and slows in long term. To be more specific, before about 160 days, the creep of concretes grows quickly. From 160 days to 400 days approximately, the creep of concretes increases gently. After about 400 days, the creep rises slowly. In the future study, the author will explore whether there is a specific time when the creep of concretes reaches a peak and stops to grow. It needs a long time and enough experience.

5. Influence of compressive stress on creep of concretes in temperature

5.1. Non-linear thermo-viscoelastic rheological mode

Since the transformation of concretes at high temperature are complex, the authors used mathematical models to represent creep in concrete. One study used a new model to explore high-temperature creep in concrete. The Non-linear thermo-viscoelastic rheological mode based on fractional derivatives at high temperature creep in concrete and use the existing experimental data with concretes under constant stress and temperatures for various aggregate types to calibrate [12]. It increases the study's accuracy. When the concretes load at the high temperature, the strain of concretes includes mechanical strain, shrinkage and drying shrinkage, thermal dilatation and transient thermal strain [12]. Therefore, in the analysis, the creep of concretes is in variable temperature, referring to Figure 8, Figure 9 and Figure 10 [12]. Three figures show the creep of the same lightweight aggregate concrete, in 22 ℃&204 ℃, 316 ℃&427 ℃ and 538 ℃&649 ℃ respectively, from a reasonable temperature gradient. It provides a strong argument for analysis.

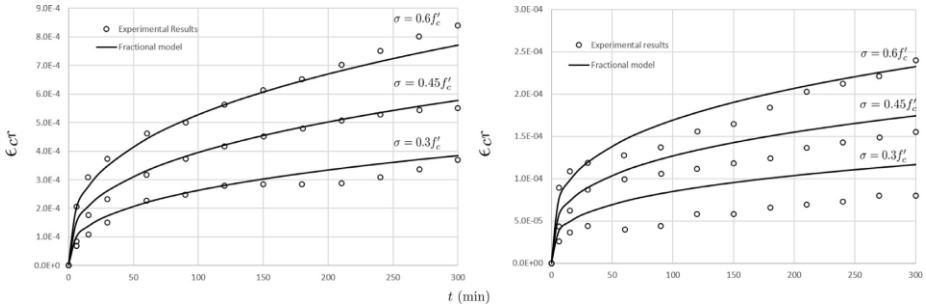


Fig. 8 Creep strains for lightweight aggregate concrete. T = 204 ℃ (left) and T = 22 ℃ (right) [12]

Figure 8 shows the variation of creep in three stresses at 204 ℃ and 22 ℃ respectively.

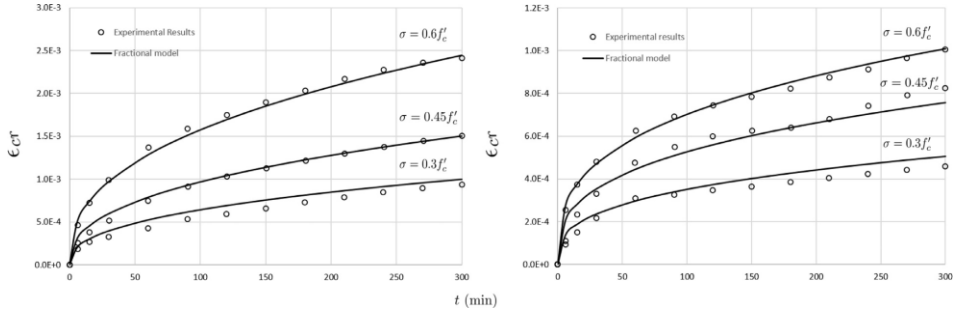


Fig. 9 Creep strains for lightweight aggregate concrete. T = 427 ℃ (left) and T = 316 ℃ (right) [12]

Figure 9 shows the variation of creep in three stresses at 427 ℃ and 316 ℃ respectively.

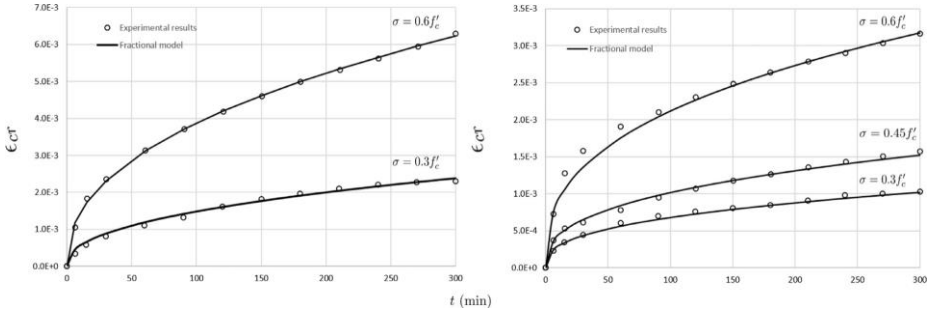


Fig. 10 Creep strains for lightweight aggregate concrete. T = 649 ℃ (left) and T = 538 ℃ (right) [12]

Figure 10 shows the variation of creep in three stresses at 649 ℃ and 538 ℃ respectively.

5.2. Analysis of compressive creep in different temperatures

The author uses contrastive analysis with the figures above to obtain the properties of concretes' creep in different temperature. 22 ℃ simulates the normal temperature in the actual building, and another temperature simulates the heat of the fire. There is a deficiency which is that the temperature gradient doesn't include the cold situation (under 0 ℃). In the figures, the same trend of all lines can be founded, which is increase as time going. It proves the property of concretes' creep in time again at 4.2 Analysis. What's more, as the stress grows, the creep rises in every graph. It proves the property of creep in the quantity of stress again at 3.2 Analysis. For temperature, the growth trend is shown from 22 ℃ to 649 ℃. To be more specific, the data in 22 ℃, 204 ℃, 316 ℃ is in the same order of magnitude which is 10^4, then the data in 427 ℃, 538 ℃ and 649 ℃ is in the same order of magnitude which is 10^3. In addition, through the calculation, the increasing multiplying power of data per 100 ℃ is different from each other. For example, the ratio of 204 ℃ to 316 ℃ in 0.6 fc is 1.33, and the ratio of 316 ℃ to 427 ℃ is 2.4. They are different completely, so the creep of concretes is non-linear. All in all, as temperature increases, the creep of one concrete grows as well without linear in the same environment.

6. Conclusion

This study found that the influence of compressive stress on creep in concretes is diversified, with factors including the amount of stress, time of loads and temperature. More specifically, the creep of concretes increases in a fixed environment as the compressive stress grows. When loaded with constant stress, the creep becomes greater with time. Then at higher temperatures and fixed stresses, concrete produces greater creep. These growth trends are nonlinear. In other words, creep becomes smaller with decreasing compressive stresses, time or temperature under the same conditions. To prevent the negative effects of creep, structural components should be subjected to low compressive stresses relative to the bearing capacity. Safety officers should be aware of the occurrence of periodic inspections of components and fires. These actions can effectively reduce the structural imbalance caused by creep.

This study provides other engineers with some properties of concrete creep that can help concrete designers use the right materials and design properly. What's more, the study provides valuable data and conclusions for future researchers to study concretes. The study summarizes three methods for obtaining useful properties of concrete creep. However, the study lacks the analysis of transient creep and other modalities in concretes. Only a few types of concrete were analyzed, which lacked comprehensiveness. As far as the current state of international research is concerned, there is little literature on concrete transient creep and the effect of mixing various factors on creep.

The author will explore this gap in the future. The authors make a recommendation that researchers should conduct more experiments on long-term creep and high-temperature transient creep to obtain actual data rather than using mathematical models to predict the data. Data are more realistic and

accurate than models. Models need data to confirm, but the available data are limited. The authors will put in experiments in this way to obtain more accurate data.

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