In this study, creep characteristics of concrete under multiaxial stress caused by uniaxial loading in confined conditions are experimentally investigated. Focus is hereby given to the creep Poisson’s ratio with regard to different degrees of lateral confinement as well as different drying conditions. The unconfined and confined specimens with the steel tube are used in the creep test. As results of the test and reproducing calculation based on the theory of elasticity, Poisson’s ratio of concrete obtained by instantaneous loading test could be also used as creep Poisson’s ratio regardless of conditions of lateral stress and drying.

1. Introduction

In accordance with requirement of higher seismic performance, concrete members with a large amount of reinforcements have been increased in Japan. When an axial load is applied to these members, lateral stress is induced in concrete due to confinement by lateral reinforcements or steel tube in addition to the axial stress. As results, concrete in the member is under multiaxial stress state. The Japan Society of Civil Engineers standard specification for concrete structures (JSCE 2017) recommends that the effect of lateral confinement on concrete creep is taken into account as much as possible. However, no quantitative evaluation method is shown. On the other hand, concrete filled steel tube (CFT) columns have been put into practical use as a new type of hybrid structure. The JSCE standard specification for hybrid structures (JSCE 2014) describes that the creep coefficient of concrete in CFT structure is estimated around 1/2 of unconfined concrete due to the effect of multiaxial stress. However, since no reliable data is available at present, same creep coefficient with unconfined concrete is adopted for concrete in CFT structure.

Creep under multiaxial stress has been studied for the sake of design of pre-stressed concrete reactor pressure vessels. Most studies have been conducted under high temperature environment of around 60°C, under conditions of the lateral stresses $\sigma_2$ and $\sigma_3$ being in the range $\sigma_2 = \sigma_3 = (0.25$ to $1.00) \times \sigma_1$ ($\sigma_1$: axial stress). On the other hand, the concrete stress confined by lateral reinforcements is estimated around $\sigma_2 = \sigma_3 \leq 0.25 \sigma_1$ and normal temperature environment around 20°C. Under the latter condition, there are a few studies (Naguib 2003; Sato et al. 1993; Ohno et al. 2015; Charpin et al. 2018). However, there are the following problems to investigate the creep characteristics experimentally under multiaxial stress. One problem is the effect of reduction of the concrete volume due to the arrangement of lateral reinforcements in the cross section of the member. The other is that the amount of reinforcements is too small to investigate the effect of the degree of confinement. Because of these problems, the creep characteristics under multiaxial stress have not yet been quantitatively clarified.

As described above, in spite of the demand in practical design, creep characteristic of concrete under multiaxial stress caused by lateral reinforcements has not been quantitatively clarified yet. In this study, we experimentally investigated the creep characteristics of concrete under multiaxial stress caused by lateral reinforcements.

2. Literature review

In order to discuss the creep characteristics under multiaxial stress due to lateral reinforcements, it is important to summarize the results of previous studies under conditions of $\sigma_2 = \sigma_3 = (0.25$ to $1.00) \times \sigma_1$ and high temperature environment around 60°C. Specially, drying condition and stress condition were focused as the influencing factor for concrete creep under multiaxial stress.

Creep Poisson’s ratio is often taken as a material parameter that represents creep characteristic under multiaxial stress condition. It is necessary to confirm the definition of Poisson’s ratio before summarizing previous studies. For an unambiguous definition of creep Poisson’s ratio, it is necessary to clarify what is the load applied on the specimen (Charpin and Sanahuja 2017). The instantaneous Poisson’s ratio $\nu_0$, and creep Poisson’s...
ratio \( \nu_{\text{cre}} \) of the specimen under uniaxial stress due to the axial compressive loading are given by:

\[ \nu_{\text{ins}} = -\frac{\varepsilon_{\text{ins}}}{\varepsilon_{\text{ins} \cdot \text{axial}}} \]  
(1)

\[ \nu_{\text{cre}} = -\frac{\varepsilon_{\text{final}} - \varepsilon_{\text{ins}} - \varepsilon_{\text{shrink}}}{\varepsilon_{\text{final}} - \varepsilon_{\text{ins} \cdot \text{axial}}} = \frac{\varepsilon_{\text{cre}}}{\varepsilon_{\text{axial}}} \]  
(2)

where

- \( \varepsilon_{\text{ins}} \): instantaneous strain, which equals to elastic strain, of concrete in the lateral direction,
- \( \varepsilon_{\text{final}} \): total strain of concrete in the axial direction,
- \( \varepsilon_{\text{ins} \cdot \text{axial}} \): total strain of concrete in the axial direction,
- \( \varepsilon_{\text{shrink}} \): shrinkage strain of concrete in the axial direction,
- \( \varepsilon_{\text{cre}} \): creep strain of concrete in the lateral direction,
- \( \varepsilon_{\text{axial}} \): creep strain of concrete in the axial direction.

Aili et al. (2016) recommended using viscoelastic Poisson's ratio based on instantaneous strain plus creep strain because scatter of that value is smaller than that based on creep strain. In this paper, creep Poisson's ratio is defined as Eq. (2). The reason why creep Poisson's is defined as above is that creep coefficient, which is the ratio of creep strain and instantaneous strain, is usually used to consider the creep behaviour in the actual structural design and is also used this coefficient for calculation of Section 5.

Figure 1 shows time-dependent creep Poisson's ratio under non-drying condition in the literature (Kennedy 1975; McDonald 1973; Ohnuma et al. 1979; Timusk 1975), while Fig. 2 shows that under drying condition (Kennedy 1975; Timusk 1975). Figure 3 shows comparison between the final values of creep Poisson's ratio and the instantaneous Poisson's ratio under non-drying condition, while Fig. 4 shows that under drying condition. In these figures, creep Poisson's ratios after more than 60 days from the loading are plotted.

In Figs. 1 and 2, the experimentally measured creep Poisson's ratio varies widely at the early stage of loading, thereafter converges to a constant value. The fluctuation of the measured value at the early stage of loading is attributable to the smallness of creep strain in the lateral direction. From these results, creep Poisson's ratio seems to have no time-dependency. According to Fig. 3, it can be regarded that creep Poisson's ratio under non-drying condition is almost same as instantaneous Poisson's ratio (Kogen 1983; Jordaan et al. 1969; Ohnuma et al. 1979). On the other hand, according to Fig. 4, creep Poisson's ratio under drying condition tends to be smaller than instantaneous Poisson's ratio. Some researchers also observed the time-dependent change of creep Poisson's ratio under drying condition (Firr 1966; Ross 1957). Moreover, they indicated creep Poisson's ratio approaches zero with time under drying condition. Meyer
(1969) suggested that this tendency of creep Poisson's ratio is attributable to the fact that lateral creep is less affected by drying action than axial creep. Concrete, which is laterally confined by reinforcements, could be considered little affected by drying because it would be protected from drying by lateral reinforcements. Therefore, it can be assumed that, if lateral stress does not affect creep in the axial direction, the creep Poisson's ratio is equal to the instantaneous Poisson's ratio and has no time-dependency. It is noted that the above discussion on drying condition of confined concrete by lateral reinforcement is merely our inference and is not a fact that has been experimentally verified. At least, confinement by steel tube can be regarded as preventing concrete from drying.

It was reported in some literature that the effect of the lateral stress on creep Poisson's ratio was not confirmed (Charpin et al. 2018; Kogen 1983; Jordaan et al. 1969; Ohnuma et al. 1979). On the other hand, Goparakrishnan et al. (1969) reported that creep Poisson's ratio is affected by the lateral stress. They reported that creep Poisson's ratio under multiaxial stress (0.09 to 0.17) is smaller than that under uniaxial stress (0.17 to 0.20). However, there is no significant difference on the values they showed.

Okajima et al. (1988) pointed out that it was not possible to obtain accurate values of strain in previous studies using cubic concrete, such as Goparakrishnan et al. (1969), because the measurement location was set on farthest points from the center of the specimen.

Therefore, it is generally accepted that the lateral stress does not affect the creep Poisson's ratio. From the above discussion, it can be hypothesized that the creep Poisson's ratio of concrete confined by lateral reinforcements is equal to that under uniaxial stress. In this study, this hypothesis is verified by experiment and reproducing calculation.

3. Instantaneous elastic deformation of concrete under multiaxial stress

In this study, steel tubes were adopted as confining materials. Elastic response of concrete confined by steel tube under axial compressive loading in Fig. 5 was formulated in order to determine the thickness of steel tube, which assures effective confinement. Following assumptions were made.

i) Concrete and steel are linear elastic materials.

ii) The heights of the concrete and steel tube are same.
iii) Confining steel tube is a plane member in the lateral (θ) and axial (z) direction.

iv) There is no bond between concrete and steel tube (σz = 0).

v) Concrete stress in the axial (z) direction distributes uniformly within cross section, and strain in the lateral (θ) direction is equal to strain in the radial direction (εθ,ins. = εr,ins.).

vi) The concrete and the steel tube deform compatibly in the lateral direction (εθ,ins. = εθ). Since it is assumed that uniaxial compressive load acts on concrete, εθ,ins. and εθ exhibit elongation.

Based on the assumptions above, stress and strain of concrete and steel tube under uniaxial loading can be calculated. Strain of concrete on the axial direction is expressed as follows.

\[ e_{c,ins.} = (1 - \alpha) \frac{\sigma_{c,ins.}}{E_c} \]  \hspace{1cm} (3)

\[ \alpha = \frac{2n
\nu_{ins.}^2}{n(1 - \nu_{ins.}) + \frac{E_s}{t}} \]  \hspace{1cm} (4)

where

- \( r \): radius of concrete,
- \( t \): thickness of steel tube,
- \( E_c \) and \( E_s \): Young’s modulus of concrete and steel tube,
- \( N \): ratio of Young’s modulus (\( n = E_s / E_c \)),
- \( \nu_{ins.} \): Poisson’s ratio of concrete on elastic behavior,
- \( \alpha \): coefficient concerning confinement level with regard to \( (\nu_{ins.} = 0.2; 0 \leq \alpha \leq 0.1; \nu_{ins.} = 0.5; 0 \leq \alpha \leq 1) \).

The coefficient \( \alpha \) represents degree of confinement in the radial direction. When \( \alpha \) is 1, the specimen is fully restrained. When \( \alpha \) is 0, the specimen deforms freely in the radial direction without any confinement.

Instantaneous elastic deformation of concrete confined by steel tube was calculated based on Eqs. (3) and (4). Table 1 lists values of the parameters used in the calculation. The parameter relating specimen size, which is \( r \), was set as the actual size of cylindrical specimen for compressive strength test. Mechanical properties of materials, which are \( E_c \), \( \nu_{ins.} \), and \( E_s \), were determined based on JSCE standard specification (JSCE 2017). Thickness of the steel tube \( t \) was investigated so that sufficient confinement effect is assured by sensitivity analysis in which the value of \( t \) in Eqs. (3) and (4) is varied.

Figure 6 shows results of the calculation. The vertical axis indicates the coefficient \( \alpha \) and the horizontal axis indicates \( r / t \), which is a thickness ratio between concrete and steel tube. The maximum value 0.1 of \( \alpha \) means that the fully lateral confinement for \( \nu_{ins.} = 0.2 \), is obtained when \( r / t \) is infinitely close to zero. According to the calculated result, the coefficient \( \alpha \) decreases with increasing of \( r / t \). This tendency denotes that confinement effect increases with increasing of the thickness of steel tube. To compare this result with the previous study, the experimental condition in the literature (Sato et al. 1993) is plotted in the figure. According to the calculation, the restraining level in the previous study was almost same as unconfined concrete. In other words, it was difficult to investigate the effect of confinement on instantaneous elastic deformation under this condition. Considering this calculation results, 20 mm thickness of steel tube as plotted in Fig. 6 is used in the test in this study.

### 4. Experimental methods

#### 4.1 Experimental conditions and specimens

Table 2 shows the materials used and mix proportions of concrete used in the test. Test series are shown in Table 3.

Three levels of initial stress were provided considering the fact that linearity between creep strain and applied stress is observed when the stress strength ratio is less than 40%. The applied stresses were approximately 6.7
N/mm², 8.9 N/mm² and 13.4 N/mm² respectively. Two kinds of loading condition, which are uniaxial loading with and without lateral confinement, were provided in order to investigate the effect of confinement on creep characteristics. Two drying conditions, which are non-drying and drying condition, were provided in order to investigate the effect of drying on creep characteristics. The inner surface of each specimen was not exposed to the ambient air. The outer surface of unconfined specimen under non-drying condition was not exposed, and under drying condition was exposed to the ambient air. Since the outer surface of confined specimen was covered with a steel tube and the end of the specimen was closed with steel plates, it can be considered that the confined specimen was hardly exposed to the ambient air.

Figure 7 shows the geometry of the specimens. The unconfined specimens were 200 mm long hollow cylinder having 32 mm inner diameter and 100 mm outer diameter. The confined specimens had a steel tube with 20 mm thickness on outside concrete. The confined specimens were prepared by casting concrete directly inside the steel tube. Grease and Teflon sheets with 0.05 mm thickness were installed between the concrete and the steel tube to reduce friction. In addition, non-loaded specimens without steel tube having same shape and dimensions with loaded specimen were made for the purpose of measuring drying shrinkage strain. The non-loaded specimens were exposed under the same drying condition with the corresponding specimen. Strain gauges with a length of 60 mm were attached to the concrete surface of the unconfined specimen. Embedded strain gauges with a length of 60 mm were embedded in the center of axial and thickness direction of the confined specimen.

The concern in this experiment is that the diameter of concrete of in confined specimen decreases due to

![Fig. 7 Geometry of specimens.](image-url)
autogenous shrinkage of concrete before loading, and as a result, a gap may occur between steel tube and concrete. On the other hand, it is believed that this concern is not critical defect to the experimental results because concrete used in this experiment is not concrete with large autogenous shrinkage strain like high-strength concrete.

The experiment was carried out in the thermo-hygrostat room whose temperature 20 ± 1°C and relative humidity 50 ± 5%. The specimens were sealed and cured by wrapping with polyethylene sheet and waterproof tape immediately after removing the mold 1 day after casting. Strain gauges were attached on the specimens before sealing. The curing period was 28 days after casting. No water loss from the specimens during curing period was confirmed by measuring the mass of the specimens. The compressive strength and Young's modulus of concrete, which were measured using cylindrical specimens of diameter 100 mm and height 200 mm cast and cured in the same manner as the creep test specimens, were 44.5 N/mm² and 31 916 N/mm² at age of 28 days, respectively.

4.2 Creep test

Figure 8 shows the apparatus for the creep tests. The unconfined and the confined specimens were placed in series. Compressive stress was induced to the specimens after curing for 28 days by a pre-stressing tendon penetrating through the center of the specimens. The procedure to induce sustained load was completed within 10 minutes. The specimens to be dried were removed from their sealing immediately before stress applied. The stress during sustained load was checked and controlled periodically by adjusting load so that measured average strain of the pre-stressing tendons becomes the designated value. At the end of the specimens, grease and a Teflon sheet were applied between the specimen and the plate to reduce friction.

Axial strains and lateral strains of the unconfined specimens were measured with strain gauges attached on the surface of the specimen as shown in Fig. 7. Axial strains of the confined specimens were measured by the strain gauges embedded in concrete. Lateral strains of confined specimens were measured by strain gauges attached on the surface of the steel tube assuming the compatibility of lateral strains of the steel tube and the concrete.

Measured strain is total strain, which is the sum of instantaneous elastic strain, creep strain and shrinkage strain as in Eq. (5):

\[
e_{\text{total}} = e_{\text{eff}} + e_{\text{shr}} = e_{\text{ins}} + e_{\text{cre}} + e_{\text{shr}}.
\]

where

\(e_{\text{total}}\): total strain,
\(e_{\text{eff}}\): effective strain of concrete,
\(e_{\text{ins}}\): instantaneous strain of concrete,
\(e_{\text{cre}}\): creep strain of concrete,
\(e_{\text{shr}}\): shrinkage strain of concrete.

Based on Eq. (5), creep strain of the specimen was evaluated by subtracting instantaneous strain, which is defined as measured strain within 10 minutes after loading in this study, and drying shrinkage strain measured in the non-loaded specimen from measured total strain. In this paper, contraction strain is defined as negative, while elongation strain is defined as positive.

In the literature (Rüsch et al. 1983; Neville et al. 1983), the strain that occurs when a load is applied for less than 1 minute is defined as the instantaneous strain corresponding to the secant modulus of elasticity. On the other hands, the time-dependent component included in the strain occurring within the range of 2 to 10 minutes is small (Neville et al. 1983). Therefore, it can be regarded that the definition of instantaneous strain in this paper is appropriate. However, this definition of instantaneous strain is debatable with regard to the up-to-date standards for creep testing, where the creep behavior of cementi-
tious materials is derived from short-term tests with loading duration of less than 5 minutes (Delsaute and Staquet 2020).

5. Experimental results and discussion

5.1 Effect of confinement on creep of concrete

Figure 9 shows the time-dependent total strains of the unconfined specimens, while Fig. 10 shows that of the confined specimens. Figure 11 shows the time-dependent shrinkage strains of the non-loaded specimen. Figure 12 shows the time-dependent effective strains, which is evaluated as a difference between total strain and shrinkage, of the unconfined specimens, while Fig. 13 shows that of the confined specimens.

According to Figs. 12 and 13, it can be confirmed that lateral strains is generally smaller than axial strains. In particular, the lateral creep strains are as small as 50 micro or less through the loading period. Therefore, the tendency of the lateral creep should be discussed carefully.

In Fig. 14, the effective axial strains under confined and unconfined conditions are compared. The effective axial strains of the confined specimens are smaller than those of the unconfined specimens. It is inferred that restraint of the expansion in the lateral direction by lateral reinforcement caused this phenomenon. This phenomenon was remarkable at the initial stage of loading.

The differences of instantaneous strains are summarized in Table 4.

Table 4 Instantaneous strains of the specimens of series “UN” and “CN”.

| Instantaneous elastic strain | UN | CN | CN / UN |
|-----------------------------|----|----|---------|
| $\sigma / f'_{c}$ = 0.15    | -198.0 | -180.8 | 0.913 |
| $\sigma / f'_{c}$ = 0.20    | -275.2 | -264.2 | 0.960 |
| $\sigma / f'_{c}$ = 0.30    | -441.6 | -365.5 | 0.828 |

UN: Unconfined, non-drying; CN: Confined, Non-drying

It is necessary to confirm the linearity among instantaneous strain, creep strain and applied stress of specimens under non-drying. Figure 15 shows the relationship between the effective strain on 1, 7, 28 and 60 days and stress-strength ratio of unconfined specimen under non-drying condition, while Fig. 16 shows that of confined specimen. According to Figs. 15 and 16, it can be regarded that effective axial strains are approximately proportional to the applied stress. Therefore, in this study, both instantaneous strain and creep strain in the axial direction under non-drying condition can be regarded as having a linear relationship with applied stress.

Instantaneous strains of the confined concretes were calculated by Eqs. (3) and (4) using the mechanical properties in Table 5, which were determined from instantaneous strains of the unconfined specimens. In ad-
dition, effective strain was calculated based on the following equation under the assumptions that the creep Poisson’s ratio of concrete is equal to its instantaneous Poisson’s ratio and no creep occurs in steel.

\[ \varepsilon_{\text{eff. (confined, cal)}} = (1 + \frac{\varepsilon_{\text{cre. (unconfined, exp)}}}{\varepsilon_{\text{ins. (unconfined, exp)}}}) \cdot \varepsilon_{\text{ins. (confined, cal)}} \]  

(6)

where,
- \( \varepsilon_{\text{eff. (confined, cal)}} \): Calculated effective strain of confined specimen,
- \( \varepsilon_{\text{ins. (confined, cal)}} \): Instantaneous strain of confined specimen calculated by Eqs. (3) and (4),
- \( \varepsilon_{\text{cre. (unconfined, exp)}} \): Creep strain of unconfined specimen and
- \( \varepsilon_{\text{ins. (unconfined, exp)}} \): Instantaneous strain of unconfined specimen.

If the calculated results are in good agreement with the experimental results, the creep Poisson’s ratio of the confined concrete are regarded to be the same as that of the unconfined concrete. In other words, the confinement condition, which causes either uniaxial or multiaxial stress states, does not affect creep Poisson’s ratio. Figure 17 shows the experimental and calculated effective axial strains as a function of time. According to Fig. 17, the experimental and the calculated results tend to agree with each other in all cases of stress strength ratio. Hence, it is confirmed that creep Poisson’s ratio is independent from stress condition, which is either uniaxial or multiaxial. The creep deformation of concrete under confined condition can be estimated from the creep coefficient and the creep Poisson’s ratio of the concrete obtained under uniaxial stress condition.

### Table 5 Instantaneous mechanical properties of concrete.

| \( \sigma/f_c' \) | \( E_c \) (N/mm²) | \( v_{\text{ins.}} \) (-) |
|-----------------|-----------------|-----------------|
| 0.15            | 31869           | 0.202           |
| 0.20            | 32703           | 0.175           |
| 0.30            | 28808           | 0.190           |
5.2 Effect of drying on creep Poisson's ratio
At first, the effect of drying on creep is discussed based on the test results of creep of unconfined specimens under non-drying and drying conditions.

Figure 18 shows the time-dependent total strains of the unconfined specimens under drying condition. Figure 19 shows the time-dependent shrinkage strains of the non-loaded specimens under conditions of non-drying and drying. Figure 20 shows the time-dependent effective strains of the unconfined specimens under drying condition. According to Figs. 18 and 20, the creep rate at a stress-strength ratio of 0.15 appears faster than that at a stress-strength ratio of 0.20. The reasons for this include the difference in drying shrinkage strain between specimens, the error due to the strain measurement position, and the failure of stress transmission in the apparatus of creep test, although the clear cause is not obvious. According to Figs. 12 and 20, axial creep strains under drying condition are greater than under non-drying condition.

It is necessary to confirm the linearity among instantaneous strain, creep strain and applied stress of unconfined specimens. Figure 21 shows the relationship between the effective strain on 1, 7, 28 and 60 days and stress-strength ratio under drying condition. According to Fig. 21, under drying condition, although it can be regarded that effective strains are approximately proportional to applied load within 28 days after loading, effective strains and stress intensity ratios show a non-linear relationship at 60 days after loading.

Next, the effect of drying condition on the creep Poisson's ratio \( \nu \), which is the ratio of the axial creep strain to the lateral creep strain, is discussed. Figure 22 shows creep Poisson's ratio of the unconfined specimens as a function of time. In Fig. 22, the mean value of the instantaneous Poisson's ratio is also plotted by dotted line. As already discussed in section 5.1, creep Poisson's ratio of the unconfined specimen can be regarded as almost equal to that of the confined specimen. Therefore, creep Poisson's ratios of the confined specimen are not shown in Fig. 22. Figure 23 shows the correlation between
instantaneous Poisson's ratio and creep Poisson's ratio obtained in this study and in the literature (Kennedy 1975; McDonald 1973; Timusk 1975; Ohnuma 1979). According to Fig. 23, although the correlation between creep Poisson's ratio under non-drying condition at 60 days after loading and instantaneous Poisson's ratio is scattered among each study, they can be regarded as almost equal. On the other hand, under drying condition, creep Poisson's ratios after 60 days from the start of loading are smaller than their instantaneous Poisson's ratios.

This tendency of creep Poisson's ratio under drying condition can be confirmed in previous studies (Firr 1966; Kennedy 1975; Ross 1957; Timusk 1975). Creep Poisson's ratio obtained in this experiment under drying condition is sensitively influenced by the process of subtracting shrinkage strain from effective strain. Furthermore, even if such process is performed precisely, the difference of the axial shrinkage strain between the non-loaded specimen and the loaded specimen are concerned. According to the theory of micro-cracking, which is suggested as a mechanism of drying creep, axial shrinkage strain of the loaded specimen is smaller than that of the non-loaded specimen because the loading prevents micro-cracking perpendicular to the load. On the other hand, shrinkage strain perpendicular to the load of the loaded specimen is equal to that of the non-loaded specimen. It would be expected that obtained creep Poisson's ratio in this experiment includes anisotropy of shrinkage strain in the loaded specimen that discussed above. It can be regarded that creep Poisson's ratio determined by considering this difference of axial shrinkage strain is larger than apparent creep Poisson's ratio determined by subtracting shrinkage strain of the non-loaded specimen from effective strain of the loaded specimen. Hence, creep Poisson's ratio of the unconfined specimen under drying condition would approach its creep Poisson ratio under non-drying condition. In other words, it is inferred that drying little affects to the creep Poisson's ratio. In this paper, the effect of drying on creep Poisson's ratio was not directly inspected in considering of the anisotropy of shrinkage strain in the loaded specimen. However, the tendency of the creep Poisson's ratio by the biaxial creep test (Charpin et al. 2018) in which there is no difference of shrinkage strain between the loaded specimen and the non-loaded specimen supports this inference.

### 6. Conclusions

1. The experiments could not determine a significant difference of creep Poisson's ratio for non-drying concrete in confined and unconfined conditions.
2. Creep Poisson's ratio of concrete under uniaxial stress and non-drying condition equal to its instantaneous Poisson's ratio and has no time-dependency.
3. Focusing only on the experimental results, it was confirmed that creep Poisson's ratio of the unconfined specimen under drying condition was smaller than instantaneous Poisson's ratio.
4. However, we believe that creep Poisson's ratio of unconfined specimens is equal to its instantaneous Poisson's ratio regardless of drying condition. The reason for this inference was the possibility of anisotropy of micro-cracking on the concrete surface with drying. However, this reasoning has not been confirmed as an experimental fact. Further investigation is necessary.

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