Analysis of the long-term deformation of SRC columns by the moisture diffusion

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ABSTRACT

The objective of this research is to demonstrate the effect of wide-flange steel geometry on the long-term deformation of steel reinforced concrete (SRC) column. It is widely recognized that the moisture diffusion of concrete affects the long-term deformation such as drying shrinkage and creep. It can be inferred that the long-term deformation of SRC column is different from that of ordinary RC column because the wide flange steel in SRC column disturbs the moisture diffusion. It means that the wide-flange steel makes the moisture diffusion slower and consequently long-term deformation develops slower.

In this paper, the analysis method that can analyze the long-term deformation from the change of the relative humidity inside the concrete is suggested to consider different moisture diffusion process in RC and SRC column. Then, some typical sections of SRC column are analyzed to show the effect of wide-flange steel clearly. The analytical results of those sections are compared with the result of RC column with same condition and discussed. This is a preliminary study for modifying the existing model equations thus it is focused on the establishment of analysis method and identifying how the long-term deformation of SRC column is different from RC column.

1. INTRODUCTION

Many researchers have carried out researches on the long-term deformation of concrete. However, researches about the long-term deformation of concrete such as steel-reinforced concrete(SRC) whose drying is restrained are not sufficient. The restrained drying by the wide-flange steel in SRC results in the change of the humidity distribution of the column section. Therefore, the analysis method which can reflect the change of the pore relative humidity on the calculation of the long-term deformation of concrete is used for analyzing the characteristics of SRC column. Various kinds of SRC columns are analyzed based on the method, and the effect of the wide-flange steel geometry on the long-term deformation of SRC column is determined. This research

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gives an approximate prediction of the long-term deformation of SRC column to consider the difference of the SRC column compared to the RC column in the structures.

2. CALCULATION OF THE LONG-TERM DEFORMATION FROM THE CHANGE OF THE PORE RELATIVE HUMIDITY

Schematic explanation of the calculation process of the long-term deformation is as shown in Fig.1. The method was introduced in Ghali(2002).

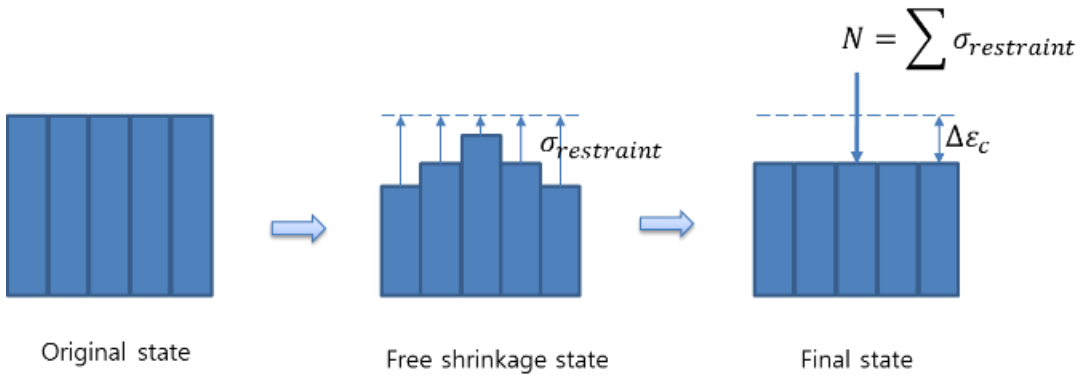


Fig.1 Calculation of strain during a time step

If the total strain of each element is restrained, the restraint stress arose from the free shrinkage can be calculated as in Eq.(1). Free shrinkage includes the basic creep and strain related to the drying process such as drying shrinkage and drying creep. .

$$\Delta\sigma_{restraint}(t_i,t_{i-1}) = -\frac{E_c(t_{i-1})}{1+\phi_{basic}(t_i,t_{i-1})}\left(\sum_{j=1}^{i-2}\frac{\Delta\sigma_c(t_{j+1},t_j)}{E_c(t_j)}(\phi_{basic}(t_i,t_j)-\phi_{basic}(t_{i-1},t_j))+\Delta\varepsilon_{drying}(t_i,t_{i-1})\right) \quad (1)$$

Strain related to the drying process in Eq.(1), $\Delta\varepsilon_{drying}(t_i,t_{i-1})$, is calculated by Eq.(2). Eq.(2) contains the change of the pore relative humidity in the term $\Delta f_s(h)$ which gives different result in RC and SRC column because of the different distribution of the pore humidity.

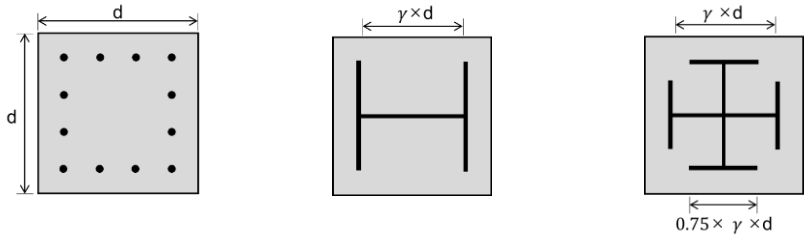
$$\Delta\varepsilon_{drying} = \varepsilon_s^0 g_s(t)\left(1+r\sigma(t)\right)\Delta f_s(h) \quad (2)$$

where ε_s^o is the ultimate free shrinkage, $g_s(t) = E_c(t_0)/E_c(t)$, and the function $f_s(h) = 1-h$ is chosen in this paper. Because the humidity h is different everywhere in the section during the diffusion process, Eq.(2) should be calculated at every points in the section.

The final shrinkage of the column section during a time step can be calculated by summing up the restraint stresses, and applying it to the section reversely. The same process should repeated to get the shrinkage at the next time step.

3. COMPARISON OF THE LONG-TERM DEFORMATION OF RC AND SRC COLUMN

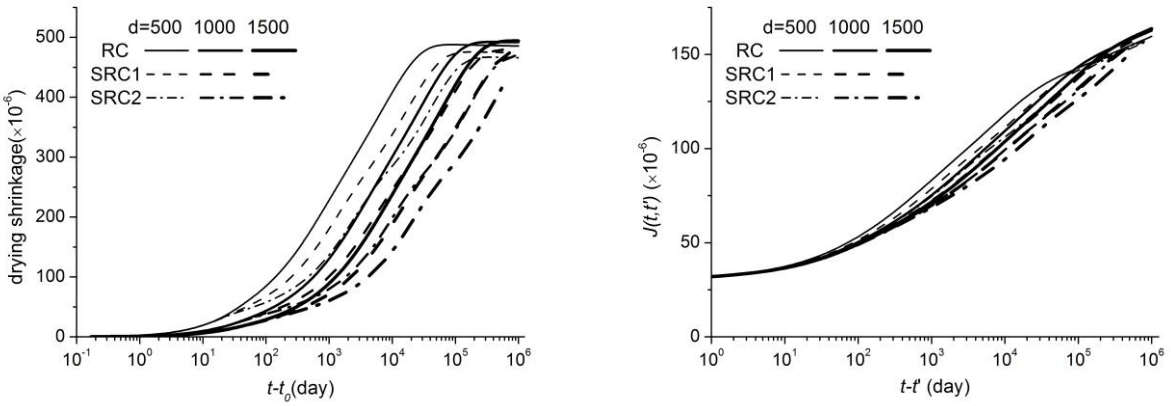
Fig. 2 shows RC and SRC columns for the long-term deformation analysis and their marks. These sections are selected to represent typical RC and SRC sections.



(a) RC (b) SRC1 (c) SRC2

Fig.2 Column section layout

Fig.3 shows the analysis results of three types of columns whose sizes are 500mm, 1000mm and 1500mm. Their γ marked in Fig.2 is 0.9. Environmental temperature is 20℃ and ambient relative humidity is 50%.



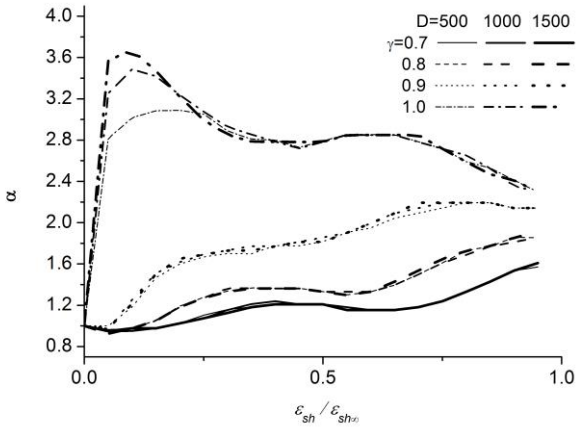
(a) Drying shrinkage (b) Creep

Fig.3 Long-term deformation of RC and SRC columns

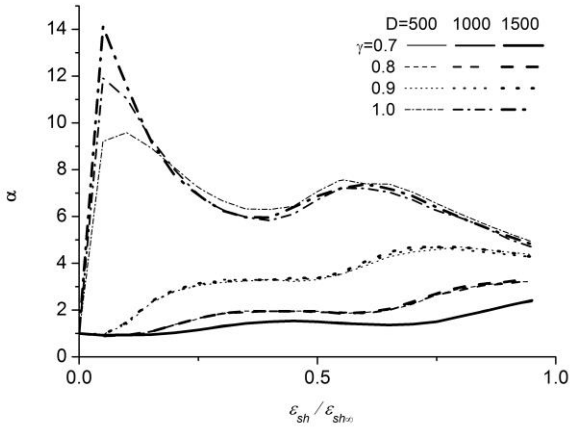
The fact that it takes more time for SRC column to reach the same shrinkage as RC column can be observed from Fig.3. If the time ratio taken by RC and SRC until the certain shrinkage is expressed as a parameter α, it quantitatively represents the delay of the long-term deformation of SRC column compared to RC column. If the ratio, α, is 2, for example, it means that it takes twice the time for SRC column to reach the same deformation of RC column. In other words, the ratio represents the amount of horizontal shift of deformation curve of SRC column in comparison with RC column.

The time ratio α analyzed from three different sizes of columns with four different portions of wide-flange steel is presented in Fig.4. The ratio α becomes larger when the wide-flange steel disturbs the moisture diffusion more. Therefore, α for SRC2 section is larger than α for SRC1.

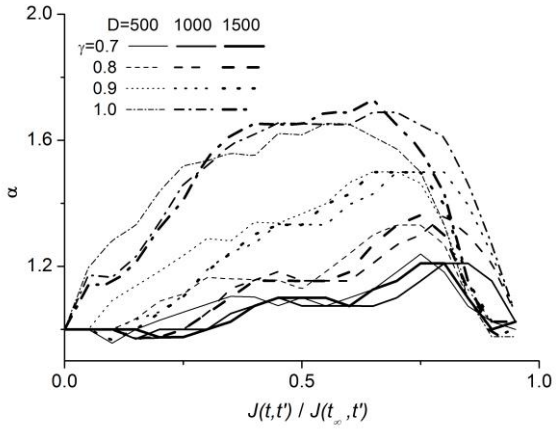
In conclusion, the long-term deformation of SRC columns develops α times slower and the value of α is closely related the wide-flange-steel geometry in SRC column.



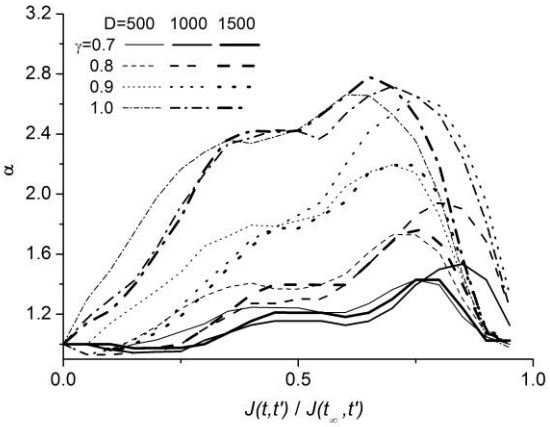
(a) Drying shrinkage of SRC1



(b) Drying shrinkage of SRC2



(c) Creep of SRC1



(d) Creep of SRC2

Fig.4 Equivalent age of SRC columns

4. CONCLUSIONS

As observed so far, the inner configuration of the section affects moisture diffusion and long-term behavior of concrete consequently. If the wide-flange-steel geometry of the section disturbs moisture diffusion, the drying related strain develops slower as a result of diffusion speed. In other words, the time ratio α becomes bigger as the portion of the wide-flange steel γ becomes bigger. Therefore, the long-term deformation of SRC column should be predicted by considering the effect of the wide-flange steel. The difference in the long- term deformation of SRC columns caused by the wide-flange steel becomes significant as the steel disturbs the moisture diffusion more. More researches are needed to modify model equations commonly used in practice.

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