Influence of Differential Moisture Distribution on SRC Column Shortening

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ABSTRACT

Steel reinforced concrete (SRC) columns, which are widely employed in high-rise buildings, exhibit particular time-dependent behavior due to creep and shrinkage of the concrete, and this behavior may cause problems related to serviceability and structural stability. SRC columns also exhibit a time-dependent, cross-sectional relative humidity distribution that differs from reinforced concrete (RC) columns, due to the presence of an inner steel plate, which interferes with the moisture diffusion of concrete. This differential moisture distribution of SRC columns may reduce the drying shrinkage and the drying creep as contrasted with RC columns. Therefore, we propose that the differential moisture distribution be taken into account to accurately predict SRC column shortening.

1. INTRODUCTION

With the rapid increase of high-rise building construction in recent years, SRC columns have been widely used, because their sectional efficiency is higher than that of RC columns. The latest experimental research has shown that SRC column shortening tends to be overestimated by the estimation methods generally used to predict the shortening of RC columns. In the case of SRC columns, more cracks occur at the outer concrete nearest the steel section. We cannot explain these phenomena well with the existing analysis methods. Therefore a new analysis method that considers the unique properties of SRC columns is necessary to solve problems that occur in SRC columns. The progress of moisture diffusion in SRC columns is completely different from that of RC columns, because a steel section, such as a H-shaped steel section, obstructs the moisture diffusion route of the inner concrete. Consequently, the obstruction of the moisture diffusion route causes a reduction of both drying shrinkage and drying creep in the SRC columns.

In this paper, analysis on differential drying shrinkage and differential drying creep is performed by analyzing the progress of moisture diffusion at each point of an SRC column section. Finally, a new method for accurate prediction of SRC column shortening is proposed.

2. EXPERIMENT AND ANALYSIS TO OBTAIN IMPORTANT ANALYTIC VARIABLES

2.1. The determination of variables related to moisture diffusion

In this study, the CEB-FIP(90) model was adopted to determine the moisture diffusion coefficient of the concrete used in the SRC column specimens[1]. The regression analysis of the result of moisture diffusion experiment revealed D_1, the maximum of $D(H)$ for $H=1(\mathrm{m}^2/\mathrm{s})$, as the major variable[2]. The surface factor, f, was also determined to be a major variable in the same way, which defines the boundary conditions between the relative humidity on the surface of the concrete and the external relative humidity in the moisture diffusion theory[3]. The mix proportion and the shape of specimens are as follows.

Table 1. The mix proportion

Cement type	water-binder ratio(%)	fine aggregate ratio(%)	unit weight(kg/m^3)						
			water	cement	fly ash	slag	fine aggregate	coarse aggregate	super plasticizer
1	33.9	43	161	403	48	24	720	976	6.65

After initial moist-curing for 1 day, specimens were placed in a constant-temperature and constant-humidity room under conditions of 20±1℃ and 40±2% RH. Relative humidity inside the specimens was measured at distances of 3, 6, and 10 cm from the exposed surface. Moisture loss due to self-desiccation was also measured from the specimens which had been sealed on all surfaces under the same exposed conditions, to consider moisture loss due to drying alone. Moisture diffusion analysis was performed to determine D_1 and f from the regression analysis of the experimental result. The analytic result compared with the experimental result is shown in Fig. 2.

The variables determined by the regression analysis were $D_1=1.8\times10^{-6}$ m^2/h and $f=12\times10^{-6}$ m/h ; these variables were applied to the moisture diffusion analysis on the SRC column specimens to calculate both the differential drying shrinkage and the differential drying creep.

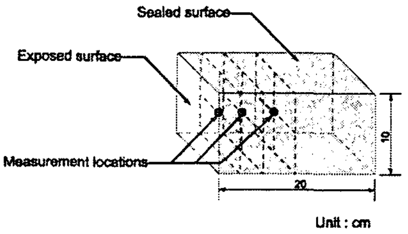


Fig. 1. The shape of specimens and measurement locations

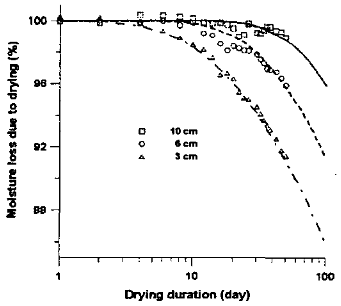


Fig. 2 Analytic results compared with experimental result

2.2. The determination of variables related to drying shrinkage and drying creep

For a given cross-section and length of time, Bazant expressed the variation of differential drying shrinkage, $\Delta\epsilon_{sh}$, and the variation of differential drying creep, $\Delta\epsilon_{dc}$, in terms of the variation of relative humidity, Δh, as follows[4].

$$\Delta\epsilon_{sh} = k_{sh}\Delta h \tag{1}$$

$$k_{sh} = \epsilon_s^0 g_s(t) \tag{2}$$

where ϵ_s^0 in Eq. (2) is a material constant representing the magnitude of the final shrinkage value.

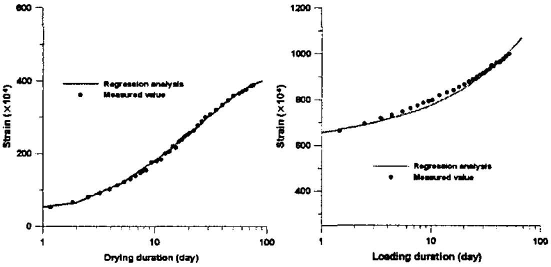
$$g_s(t) = E_c(t_0)/E_c(t),\ E_c(t) = E_c(28)\sqrt{\frac{t}{4+0.85t}},\ E_c(28) = 33w^{1.5}\sqrt{f_{ck}}$$

$$\Delta\epsilon_{dc} = k\Delta h \tag{3}$$

$$k = k_{sh}\, r\sigma\, sign(\bar{h}) \tag{4}$$

where r in Eq. (4) is a constant for shrinkage.
σ is a stress in a cross-section.
$sign(\bar{h})$ is the sign of the microdiffusion flux, $\bar{h}$.

In this paper, ϵ_s^0 in Eq. (2) and $r\sigma$ in Eq. (4) were the major variables to be determined by the regression analysis of the experimental results ; $r\sigma$ was modified as $a\sigma + b$. The variables determined by the regression analysis, as shown in Fig. 3, were $\epsilon_s^0 = -1000\times10^{-6}$, $a = -5.05\times10^{-7}$, and $b = 0.985$, and these variables were applied to the column shortening analysis of the SRC column specimens.



(a) Drying shrinkage, (b) Drying creep

Fig. 3. The results of regression analysis of both drying shrinkage and drying creep

3. PREDICTION OF COLUMN SHORTENING OF SRC COLUMNS WHEN CONSIDERING DIFFERENTIAL MOISTURE DISTRIBUTION

3.1. Moisture diffusion analysis of a SRC column specimen versus that of RC column

The results of moisture diffusion analyses of a SRC column specimen and a RC column are shown in Fig. 4. A RC column was modeled as a plain concrete column by disregarding the effect of bars obstructing the moisture diffusion route.

As shown in Fig. 4, moisture diffusion inside the steel section in a SRC column occurs slower than that inside a RC column this may lead to less SRC column shortening than that of a RC column. In addition, the moisture diffusion outside the steel section in a SRC column progresses rapidly as compared with that of a RC column ; this may lead to the appearance of more cracks in a SRC column than in a RC column.

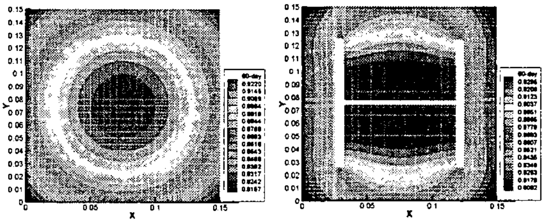


Fig. 4. The results of moisture diffusion analyses of SRC and RC columns at 60 days

3.2 Column shortening analysis of a SRC column specimen considering differential moisture distribution

The results from sections 2.2 and 3.1 were applied to a column shortening analysis of a SRC column specimen.

Figure 5 shows an analysis that considers the differential moisture distribution within a given cross-section to be more accurate than an analysis that disregards the differential moisture distribution. Therefore, to predict the column shortening of SRC columns more accurately, we propose that the differential moisture distribution, caused by the obstruction of the moisture diffusion route, should be taken into account during column shortening analyses.

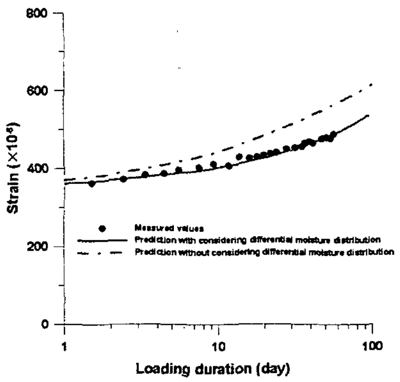


Fig. 5. Column shortening analysis considering differential moisture distribution

4. CONCLUSION

We investigated the differential moisture distribution caused by the obstruction of the moisture diffusion route in SRC columns to demonstrate its relation to accurate prediction of SRC column shortening. From the results of this investigation, the following conclusions can be drawn:

1. Overestimation of SRC column shortening may occur with use of existing prediction models, all of which exclude the effects of differential moisture distribution.
2. More accurate prediction models of SRC column shortening will consider that the differential moisture distribution in SRC columns, caused by obstruction of the moisture diffusion route, affects both drying shrinkage and drying creep.

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