Size effect on long term deflection of RC and PC bridges

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1. Introduction.

At design stage, concrete structures must be designed following a strength criterion, whose are generally extrapolated to sizes that are often much larger than a structural size that can be tested in the laboratory, to guarantee its safe structural life.

Until now, most of the studies in the matter of size effect were focused on assessments of failure strength of concrete. On the other hand, previous works that treated about long-term deflection phenomena only discussed its impact on the structural durability. However, previous studies have never discussed about size effect on long-term deflection, which implies that to nonlinear analysis is the only mean to implicitly evaluate it and there is no a basis data to explain whether or not this behavior affects the structural safety.

This works aims to clarify the nonlinear characteristics of size effect on long-term deflection behavior. Hence, the dominant factors on the variation of size effect in time-dependent deflection will be discussed, through numerical simulations.

Moreover, the difference of size effect on long-term deflection in comparison with shear strength criteria will be investigated to understand its importance on safety structural designs.

2. Experimental Study.

2.1 Specimen details and exposure-loading test

As a starting point, an exposure loading-test was conducted to verify the long-term deflection characteristics of concrete member with different volume-surface ratio.

RC and PC slabs with 100 mm (height)×300 mm (width)×3900 mm(length) of geometry, were adopted for this experiment, as it is illustrated in **Fig. 1abcde** to observe the difference of time-dependent deflection through variation of superficial drying-swelling (volume-surface ratio), at two categories of concrete structures. RC & PC slabs and prismatic specimens were installed during winter, at campus of Nagaoka University of Technology, where exposure began by November 4th, 2017. The test setting was carried out following the diagram of **Fig. 1a.** The deflection was measured by displacement meters, located in 3 positions at bottom surface of the slab. The environmental conditions were monitored, utilizing a weather station located near of specimen set, at intervals of one hour. Currently, the present exposure-loading test is still going on, gathering measurements.

2.2 Results & discussion.

Measurements results were summarized for 360 days of exposure. The results of deflections at mid span of RC and PC slabs are plotted as dotted lines, in **Fig. 2** and **Fig. 3**, respectively. Observing these, the increase of time-dependent deflection with the increasing of surfaces exposed to sunlight and rain, on RC slabs as well as PC slabs, was confirmed.

Therefore, based on experimental observations, it was concluded that the rate of long-term deformation is affected by the number of surfaces exposed to sunlight and rain.

3. Numerical verification.

Numerical analysis of this study was performed discretizing the slabs into portions where through moisture transport as well as stress-strain analysis was carried out to compute the curvature and deflections of at mid span of the slab. Numerical computations of time dependent deflections of RC and PC slab

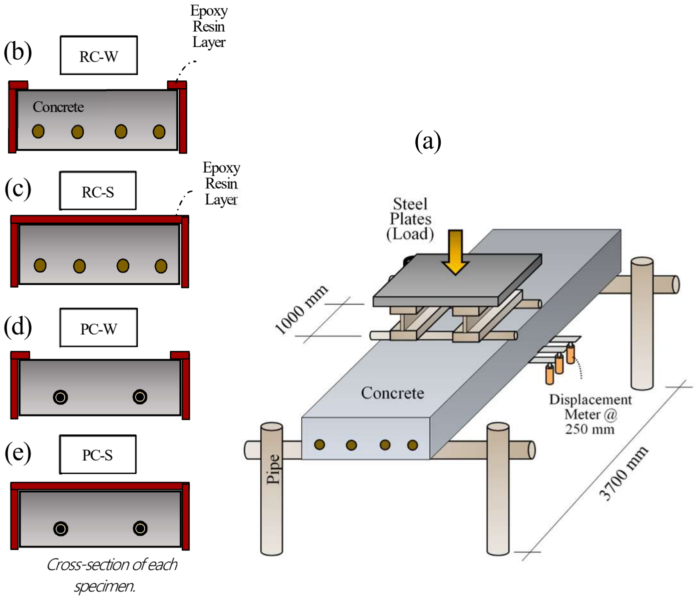

Fig. 1: Specimen seal conditions and exposure-loading test layout.

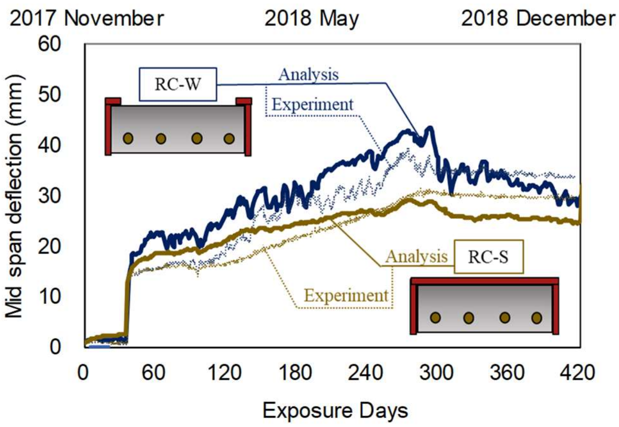

Fig. 2: Comparison of analytical results and experimental data of RC slabs deflections.

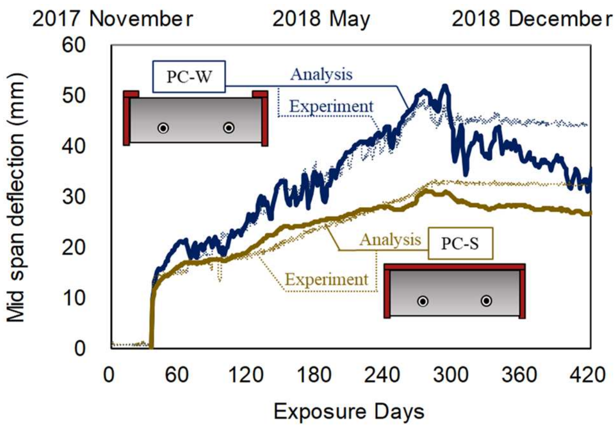

Fig. 3: Comparison of analytical results and experimental data of PC slabs deflections.

were plotted as solid lines of **Fig. 2** and **Fig. 3**, respectively. Observing these results, it was confirmed that computation models can describe the tendency of time-dependent deflection of each specimen, considering shrinkage distribution at cross section, creep, its sealing conditions as well as environment conditions.

4. Study of size effect on long-term deflection

Size effect on long-term deflection was investigated through numerical simulations, varying structural sizes on two different shapes: Prismatic girder and Box Girder.

The computations were conducted on 50 years of exposure period by considering structural self-weight as dead loads. Calculations results of relative values of time-dependent deflection were plotted on **Fig. 4** and **Fig. 5.** Observing these results, the decreasing of ambient actions on time-dependent deflection when member size increase, was confirmed. Furthermore, was observed that fluctuations of time-dependent deflection decreases with the increasing of structural size.

Moreover, deflections at 50^{th} year of member exposure were summarized against to member size, as its exhibited on **Fig. 6** and **Fig. 7**. Through these results, its remarkable to concluded that the nonlinearity of size effect on long-term deflection was clarified.

5. Conclusions

This research was focused to study the nonlinear characteristics of size effect on long-term deflection behavior, to understand its importance on structural design, as it is considered in failure strength criteria. Following this basis, experimental and analytical studies of exposure-loading test were carried out and, the earned remarks were summarized as follows:

1. Numerical models that were developed for hygrothermal analysis, were couple with stress-strain models to predict long-term deflection and these were verified by a comparison of experimental data of exposure tests.
2. Long-term deflection characteristics were observed and summarized through considerations of surface-volume ratio of concrete member.
3. Size effect on long-term deflection was clarified through numerical simulations. The obtained results demonstrated the decreasing of ambient action effects on long-term deflection as the structure size increases. Also, fluctuations of time-dependent deflection decreases when structural size increase.

In other words, remarks from above does implies that sizes effect on long-term deflection reduce the risk of serviceability from long-term deflection.

References.

[1] Zdenek P. Bazant and Jin-Keun Kim, Size effect in shear failure of longitudinally reinforced beams, ACI Journal 81-38, 1984, pp. 456-468.

[2] Toru Shiga, Tetsuo Abe, Masataka Watanabe, Takumi Shimomura, 2016, *Influence of environment on long-term deflection of RC and PC beams exposed to ambient conditions*, Proceedings of the Japan Concrete Institute, Vol.38, No.1, pp. 483-488.

[3] T. Shimomura and K. Maekawa, 1997, *Analysis of the drying shrinkage behavior of concrete using a micromechanical model based on the micropore structure of concrete*, Magazine of Concrete Research, 49, No. 181.

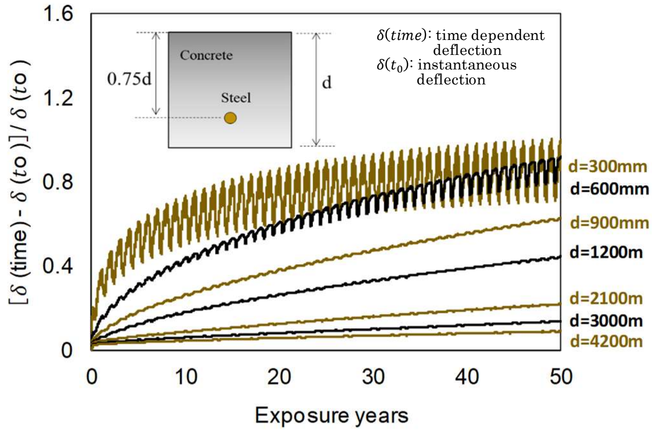

Fig. 4: Relative values of time-dependent deflections of PC prismatic girders.

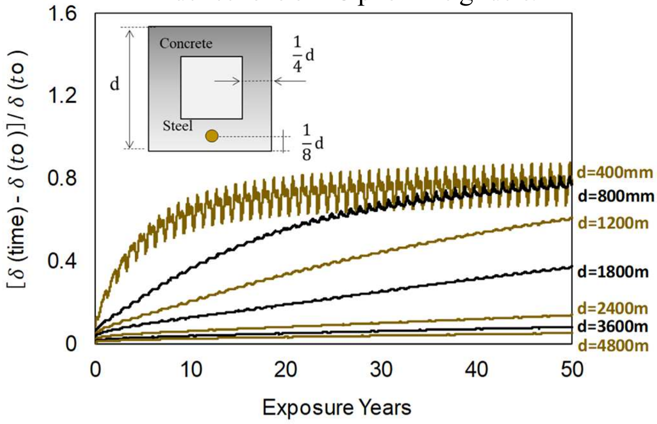

Fig. 5: Relative values of time-dependent deflections of PC box girders.

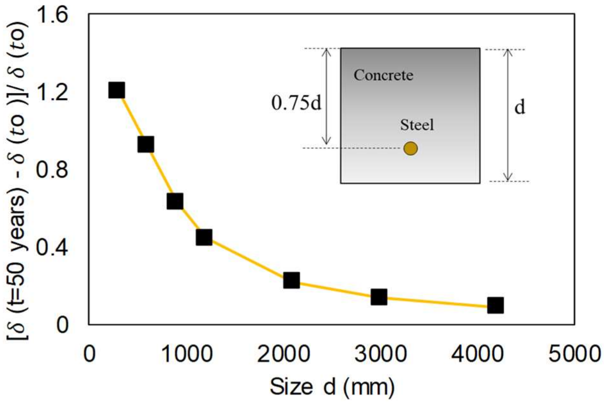

Fig. 6: Size effect of time-dependent deflections of PC prismatic girders.

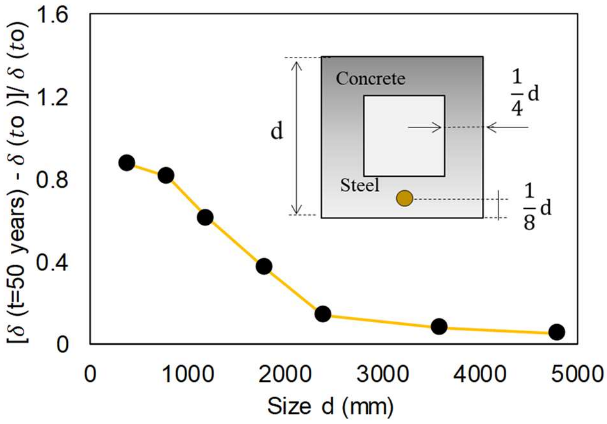

Fig. 7: Size effect of time-dependent deflections of PC box girders.