Study on evaluation method for autogenous shrinkage in dam concrete

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In thermal crack control of massive concrete structures, it has recently become general that both volume change of concrete due to heat of cement hydration and autogenous shrinkage of concrete are considered as the causes of early-age cracking. However in Japan and around the world there has been very little research or measurement of autogenous shrinkage applicable to concrete dams, in which lean-mixed concrete with less binder is used. As a result, in the design and construction of concrete dams the influence of autogenous shrinkage has so far not been taken into account.

In this paper, a new practical test method is proposed for the autogenous shrinkage of concrete. Using the new method at several dam construction sites, it is demonstrated that considerable shrinkage occurs with certain types of cement and concrete mix proportions.

Details of the test setup for measuring the autogenous shrinkage strain of dam concrete with a maximum aggregate size of 150mm are given in Fig. 1. Measurement results for the autogenous shrinkage of external concrete (Cement content : $C=190kg/m^3$) with several types of cement used in dam construction are shown in **Fig. 2**. It is clear from **Fig. 2** that autogenous shrinkage of external concrete continues for approximately one year. Also of note is that while the one-year autogenous shrinkage strains of external concrete mixed with moderate-heat Portland cement (M), moderate heat fly ash cement (content of fly ash 30%) (MF) and low heat generation and shrinkage controlled blast furnace cement with fly ash content of 15% (LBB+F) are less than 50 to 60 x 10^{-6}, that of external concrete with blast furnace slag cement type-B (BB) is greater than 100 x 10^{-6}.
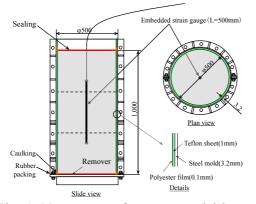

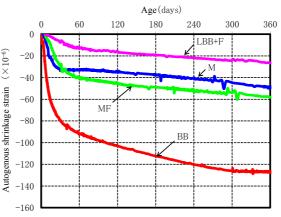Fig. 1 Measurement of autogenous shrinkage of concrete with full-sized aggregate

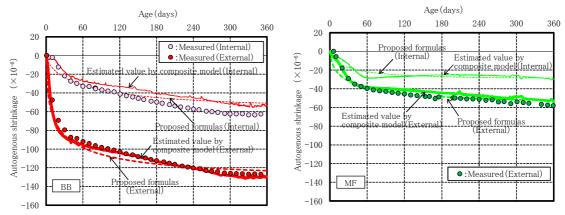Fig. 2 Measured autogenous shrinkage strain of external concrete with full-sized aggregate

Fig. 3 Comparison with estimated value by composite model, predicted value by proposed formulas and measured value of autogenous shrinkage strain of internal and external concrete (BB and MF).
[External concrete : Concrete on dam surface that requires high watertightness and durability (C=190kg/m³).
Internal concrete : Concrete inside dam with high economic efficiency suppressing heat of cement hydration (C=130kg/m³).]

These results offer the new understanding that autogenous concrete shrinkage should not be ignored as a cause of thermal cracking in dam concrete.

A further finding is that the amount of autogenous shrinkage that will occur in concrete with full-size aggregate can be estimated on the basis of a composite model and the measured autogenous shrinkage of wet-screened concrete in which aggregate particles lager than 40mm have been removed. Based on this understanding, formulas to predict the autogenous shrinkage of concrete for various type of cement used in dam concrete and for various water-to-binder (W/C) ratios are also proposed. As shown in **Fig. 3**, the shrinkage estimated using the composite model and with the proposed formulas is in good agreement with the test results, thus confirming the applicability of this method and the proposed formulas.

In **Fig. 4**, estimated values of autogenous shrinkage of various types of dam concrete obtained using the proposed formulas are plotted together with measured values. These formulas are clearly suitable for the planning and examination of thermal crack control for dam concrete. Thus it is now possible to predict the amount of autogenous shrinkage of dam concrete with a water-to-binder ratio of 45-70% and a maximum aggregate size of not more than 150mm.
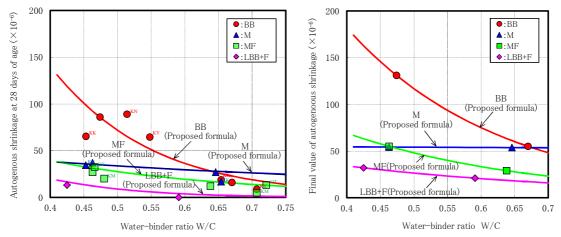

Fig. 4 Comparison of measured values of autogenous shrinkage strain of dam concrete with full-sized aggregate and values predicted by the proposed formula. [Annotated data points: measured at actual dams]