CHAPTER 7

PASTE STIFFNESS

Yomeyama, et al (1993) studied effective tensile young's modulus of early aged concrete through compressive loading history. The values of effective tensile young's modulus were obtained by sustained tension after historically sustained tension and compression test. In this study, the paste stiffness model is taken from the effective tensile young's modulus with no historically sustained tension or compression proposed by Yomeyama, et al (1993). Paste stiffness model is a function of compressive strength as follow:

$$E_p = 1.05\times10^4 \times (f_c')^{0.474} \tag{7.1}$$

where E_p = paste stiffness (kgf/cm^2)
f_c' = compressive strength of paste (kgf/cm^2)

It is considered that this equation can be used in this study because stress-strain relationships in tension before cracking have the same tendency as stress-strain relationships in compression at low stress level. From D.C. Spooner's study of the stress-strain relationship for hardened cement pastes in compression, it has been suggested that the relationships between the compressive stress and axial, lateral or volumetric strain are curvilinear.

In this study, the compressive strength of paste was tested by Deesawangnade (1994) so as to generate the paste stiffness equation in accordance with the test conditions of the tested specimens on autogenous shrinkage such as water to cement ratio and curing condition. Mix proportion for testing of compressive strength of paste by Deesawangnade (1994) is shown in Table B.1. However, the experiments of compressive strength of paste were only conducted on type 1 cement at water to cement ratios equal to 0.30 and 0.40. So, the compressive strength of paste of the other types of cement at different water to cement ratios used in the autogenous shrinkage prediction model were obtained from the comparison between the compressive strength of paste tested by Deesawangnade, T. and compressive strength of concrete with different types of cement and water to cement ratios based on Concrete Technology book (Neville and Brooks 1987). Then, the compressive strength of paste at different water to cement ratios of type 1 cement are shown in Fig. 7.1 as well as Eq. (7.2). In Thailand, type 1 cement and type 3 cement have a similar chemical composition, but different in fineness. So, the compressive strength model in Eq. (7.2) which include the effect of cement fineness can be used for both type 1 cement and type 3 cement. Type 3 cement, which has higher fineness than type 1 cement, results in greater compressive strength at early age and compressive strength will gradually increase in long term. The compressive strength of paste of type 3 cement is illustrated in Fig. 7.2. The compressive strength of paste of cement type 5 is shown in Fig. 7.3 as well as Eq. (7.3).

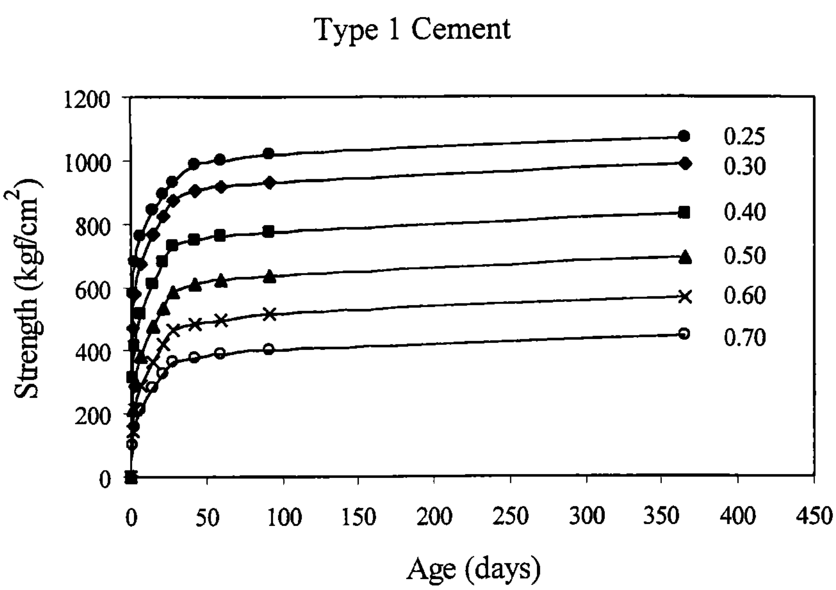

Fig. 7.1 Relationship between compressive strength of type 1 cement with fineness 3190 cm^2/g and age of testing at different water to cement ratio

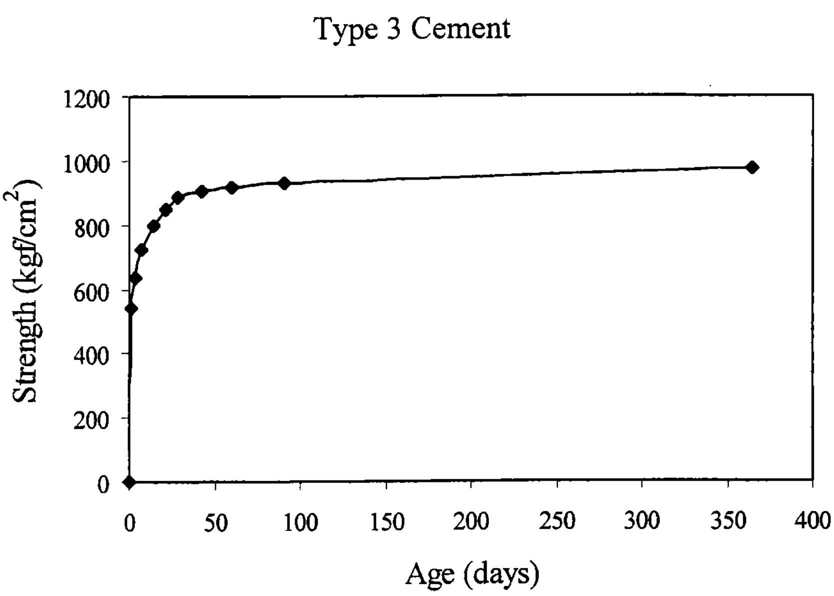

Fig. 7.2 Relationship between compressive strength of type 3 cement with fineness 4770 cm^2/g and age of testing at water to cement ratio of 0.30

For age of specimen $t \leq 28$ days

$$f_c' = \{(0.817\times\log F-1.863)\times(19.23+\exp(7.38-4.21\times w/c))\}\times t\text{^}\{(-1.089 \log F+4.817)\times(0.23\times\ln(w/c)+0.46)\} \quad (7.2a)$$

For age of specimen $t > 28$ days

$$f_c' = \{(0.191\times\log F+0.332)\times(-214.7+\exp(7.42-1.74\times w/c))\}\times t\text{^}\{(-1.089 \log F+4.817)\times(0.1\times w/c+0.01) \quad (7.2b)$$

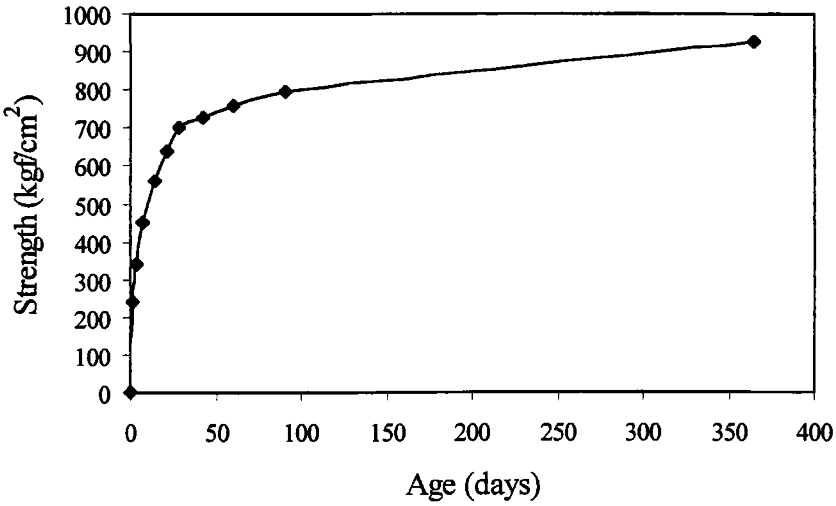

Fig. 7.3 Relationship between compressive strength of type 5 cement with fineness 3760 cm^2/g and age of testing at water to cement ratio of 0.30

For age of specimen $t \leq 28$ days

$$f_c' = 241.14 \times t^{0.32} \tag{7.3a}$$

For age of specimen $t > 28$ days

$$f_c' = 483.87 \times t^{0.11} \tag{7.3b}$$

where
- f_c' = compressive strength of cement paste (kgf/cm^2)
- F = Blaine fineness of cement (cm^2/g)
- w/c = water to cement ratio
- t = age of specimen (days)

For strength of cement-fly ash paste, we can obtain indirectly from strength model of concrete by Nipatsat (2000). The assumption is that the strength ratio of concrete without fly ash to concrete with fly ash is the same as the strength ratio of cement paste without fly ash to cement paste with fly ash.

$$\frac{f_c'_{(c)}}{f_{c+f}'_{(c)}} = \frac{f_c'_{(p)}}{f_{c+f}'_{(p)}} \tag{7.4}$$

where
- $f_c'_{(c)}$ = compressive strength of concrete without fly ash (kgf/cm^2) from Nipatsat (2000)
- $f_{c+f}'_{(c)}$ = compressive strength of concrete with fly ash (kgf/cm^2) from Nipatsat (2000)
- $f_c'_{(p)}$ = compressive strength of cement paste without fly ash (kgf/cm^2) from Eq. (7.2) and Eq. (7.3)
- $f_{c+f}'_{(p)}$ = compressive strength of cement paste with fly ash (kgf/cm^2)