Research on Temperature Stress of Large-Area Concrete Beam-Slab Structure

Li Yan-ying

Deputy Professor, Dept. of Architecture and management, Engineering College of Shanxi University , Taiyuan. China

Abstract: Large-Area Concrete beam-slab Structure mainly means the monolithically cast concrete structure whose length and width are more than maximum of the structure in the code . The influence of temperature change , shrinkage and creep on structure is the key to solving the problem . Through a practical engineering ,Shrinkage and creep formulas accord with test results are brought forward . The calculation results of shrinkage strain, temperature strain and prestressed strain coincide test results and can be directed to projects .

Keywords: large-area concrete beam-slab structure ; shrinkage ; creep ; temperature stress ;

1. INTRODUCTION

Jincheng Museum area is more than 20000m^2, two-floor frame structure, the basic column net size is 8m×8m. The building size is 64m×128m，rate of common reinforcing steel is 1.2%, rate of prestressed reinforcing steel is 0.4%. There is a post-poured strip along long-span. The prestressed bar Φ^j15.2 is used and is connected by linker.

2. TEST

The test is mainly stress rule and strain rule of two-floor large-area concrete by temperature change and concrete shrinkage and creep. The temperature stress is based on the temperature difference between indoor and outdoor and temperature observation of slab. When thermometer and oscillation strain-meter are embeded in floor, we′ll get the temperature readings and frequency at the test point. The basic assumption of calculating concrete stress by steel-meter: the steel-meter strain is as much as around concrete strain, the concrete strain is given by

$$e(t) = [N(t) - N_0]/(AE_s) + a_s[T(t) - T_0] \qquad (2.1)$$

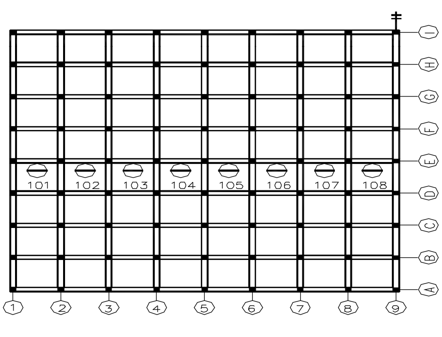


Fig.1 The test point layout

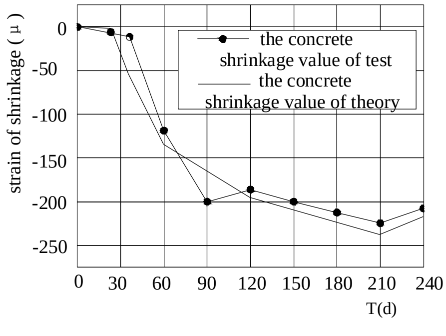


Fig.2 The test and theory value

Where N(t), T(t) are steel-meter inner force and concrete tempersture at age t, N_0 and T_0 are the steel-meter initial value after pouring and pouring temperature, A is steel area while steel-meter demarcates, equal to $140mm^2$, E_s is the modulus of elasticity of steel, is $2\times10^5 N/mm^2$， and α_s is the coefficient of thermal expansion, is 1.2×10^{-5}. The thermometer and steel-meter are emmeded along two-floor long-span. The test point is shown in Fig.1.

There are three kinds of season , sunlight and suddenness temperature difference in the temperature changes. The season is mainly taken into account in large-area concrete. According to test readings the maxium and minium of the two-floor is 32℃ and 5℃ respectively. The floor temperature is as close as weather after three days. We regard the temperature average as the weather without heat of hydration. The weather change corresponds to cosine function rule.

$$T(t) = T_m + A\cos[2np(t - t_l)/365] \tag{2.2}$$

Where T_m is the average temperature value in a year，and T_m=（T_{max}+T_{min}）/2, A is temperature scope in a year, and A=（T_{max}—T_{min}）/2, t_λ is time from temperature reaction to the first max temperature.

3. BASIC PARAMETERSS

The f_{cu} is the cube compressive strength average value at 28 days. namely f_{cu}=45Mpa. The compressive strength formula is given by

$$f_c(t) = \frac{t}{a+bt} f_c(28) \qquad a=4.2, \quad b=0.85. \tag{3.1}$$

E(t) varies as age and is given by

$$E_c(t) = E_c(28)\sqrt{\frac{t}{4.2+0.85t}} \tag{3.2}$$

Where $E_c(28)$ is the modulus of elasticity of concrete at 28 days, given by

$$E_c(28) = \frac{10^5}{2.2 + 34.7/f_{cu}} = 3.37\times10^4 N/mm^2 \tag{3.3}$$

With the main body a prism specimen is poured in worksite inside steel-meter and thermometer. The strain includes shrinkage strain and temperature change strain. We get the shrinkage strain, if subtract the temperature change strain from the test readings. Because of under the same environment, the specimen and main structure are considered the same shrinkage rules, given by

$$e_{cs}(t,t_s) = e_{cso} b_s (t - t_s) \tag{3.4}$$

Compared with the test shrinkage value, the theory formula of this project is given by

$$e_{cs} = 3.24\times10^{-4}\sqrt{\frac{t-28}{197+t-28}} \tag{3.5}$$

To large-area floor, for different shape between specimen and structure, the formula is given by

$$e_{cs} = 3.24\times10^{-4}\sqrt{\frac{t-28}{538+t-28}} \tag{3.6}$$

4. CREEP THEORY

When calculating the temperature stresses, temperature difference and the modulus of elasticity is a key to calculation. The shrinkage and creep of concrete is taken into account for enduring long –period season temperature difference. The creep is that strain varies with time during continuous loading. Creep strain is bigger 1-3 times than elastic strain. The age-adjusted effective modulus of Trost-Bazant is valid method which calculate creep concerned with long-period and suit to equation in temperature stress and shrinkage.
The concrete strain

$$e(t) = e_e(t) + e_{cr}(t) + e^0(t) \tag{4.1}$$

The strain during one-way constant stress is given by

$$e(t) = s_0 J(t,t_0) + e^0(t) \tag{4.2}$$

Where $\varepsilon^o(t)$—non-stress strain caused by shrinkage and temperature, J（t,τ_0）is called creep coefficient which express the sum of elastic and creeep per constant stress at t from τ_0.

$$J(t,t_0) = \frac{1}{E(t_0)} + C(t,t_0) = \frac{1+j(t,t_0)}{E(t_0)} \tag{4.3}$$

$$j(t,t_0) = E(t_0)C(t,t_0) \tag{4.4}$$

Where $E(\tau_0)$is the modulus of elasticity at τ_0, $C(t, \tau_0)$is called creep degree which express creep per stress.

$$e(t) = s(t_0)[\frac{1}{E(t_0)} + C(t,t_0)] + \int_{t_0}^{t}[\frac{1}{E(t_0)} + C(t,t_0)]ds(t) \tag{4.5}$$

$$e(t)=s\,(t_0)\frac{[1+j\,(t,t_0)]}{E(t_0)}+\frac{s\,(t)-s\,(t_{0)}}{E(t_0)}[1+c\,(t,t_0)j\,(t,t_0)] \tag{4.6}$$

$$e\,(t)=s\,(t_0)\frac{[1+j\,(t,t_0)]}{E(t_0)}+\frac{s\,(t)-s\,(t_0)}{E(t,t_0)} \tag{4.7}$$

$$E\,(t,t_0)=\frac{E\,(t_0)}{[1+c\,(t,t_0)j\,(t,t_0)]} \tag{4.8}$$

E(t,τ0) is called the age-adjusted effective modulus, χ（t,τ0） is called old-aged coefficient. R(t, τ0) is called relax coefficient, is given by

$$c\,(t,t_0)=\frac{1}{1-R\,(t,t_0)}-\frac{1}{j\,(t,t_0)} \tag{4.9}$$

Creep coefficient is given by

$$j\,(t,t_0)=j\,(\infty,t_0)b_c(t-t_0) \tag{4.10}$$

$$j\,(\infty,t_0)=b\,(f_c)b\,(t_0)j_{RH} \tag{4.11}$$

In the early loading, creep is bigger and time interval set less. In the latter, creep is less and time interval set bigger.

5. TEMPERATURE STRESSES CALCULATION

The shrinkage and temperature difference will cause strain. Therefore, both temperature change and shrinkage influence on structure is considered. Swell agent prevent from early cracking and prestressing is a valid measures to prevent from cracking. With the age losses of prestress decrease gradually.

We assume that common steel ,prestress steel after tension and concrete have same strain, regard the section stain distribute uniformly. We calculate its magnitude by summing shrinkage, prestress action and temperature difference respectively. Set the area of floor is A=bh, the area of common steel is A_s, the area of prestress is A_P.

5.1. Shrinkage stresses

Shrinkage stress is caused by shrinkage strain which increase gradually. Set concrete begin shrinkage at τ_s, produce shrinkage $\varepsilon_{cs}(t,\tau_s)$ at t, total strain $\varepsilon_c(t)$， stress $\sigma_c(t)$. By equilibrium of force

$$[e_c(t)-e_{cs}(t,t_s)]E_j(t,t_s)A_c+e_c(t)E_s(A_s+A_p)+K(t,t_s)Le_c(t)=0 \tag{5.1}$$

Solving and using Hooke's law gives

$$s_c(t)=\frac{-e_{cs}(t,t_s)[h(t,t_s)+u(t,t_s)]}{g_j(t,t_s)+h(r_s+r_p)+u(t,t_s)}E_j(t,t_s) \quad (5.2)$$

5.2. Temperature stresses

The temperature is cycle. If temperature begins action from age τ_j, and subsection calculate, set age τ_i , so stress from τ_i to τ_{i+1} can be expressed as

$$[e_c(t)-e_T(t,t_i)]E_j(t,t_i)A_c+[e_c(t)-1.2e_T(t,t_i)]E_s(A_s+A_p)+K(t,t_i)Le_c(t)=0 \quad (5.3)$$

$$s_c(t)=\frac{[0.2h(r_s+r_p)-u]e_T(t,t_i)}{g(t,t_i)+h(r_s+r_p)+u}E_j(t,t_i) \quad (5.4)$$

Total stresses

$$s_c(t)=\sum_{i=0}^{n}s_c(t,t_i) \quad (5.5)$$

5.3. Prestress

Prestress is sudden loading which decrease gradually under creep. Applying prestress at time τ_m ,after tension, effective prestress $\sigma_{pe}(t,\tau_m)$, equilibrium equation is expressed

$$[e_c(t)-e_{pc}(t,t_m)]E_j(t,t_m)A_c+[e_c(t)-e_{ps}(t,t_m)]E_s(A_s+A_p)+K(t,t_m)Le_c(t)=0 \quad (5.6)$$

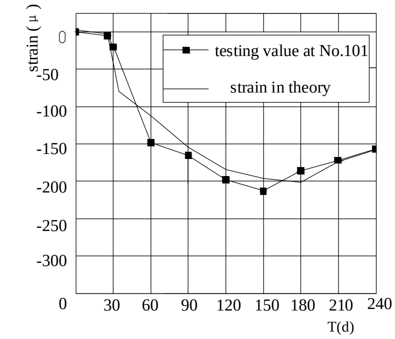
Solving

$$s_c(t)=\frac{[e_{pc}(t,t_m)-e_{ps}(t,t_m)]h(r_s+r_p)-u(t,t_m)e_{pc}(t,t_m)}{g_j(t,t_m)+h(r_s+r_p)+u(t,t_m)}E_j(t,t_m) \quad (5.7)$$

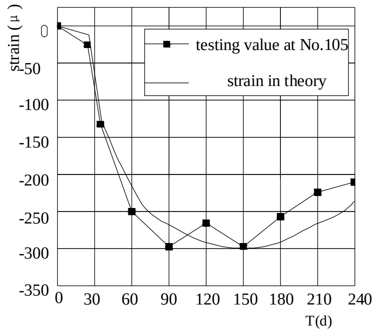
effective compression

$$s_{pc}(t,t_m)=\frac{s_{pe}(t,t_m)r_p}{1+hr_s+u(t,t_m)}E_j(t,t_m) \quad (5.8)$$

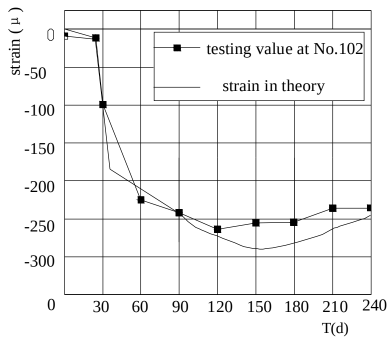
5.4、Comparsion theory calculation with test value



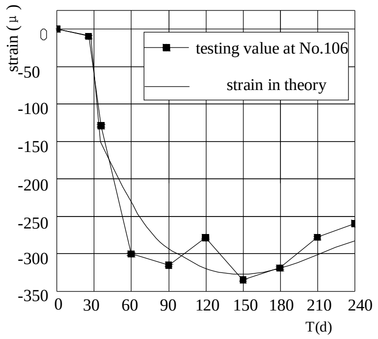
Test value at No.101 and theory



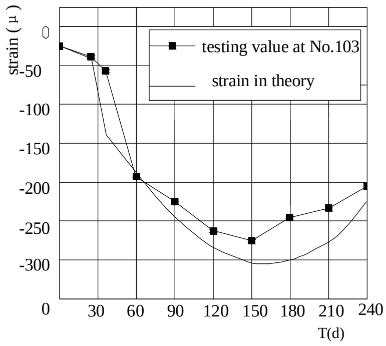
Test value at No.105 and theory



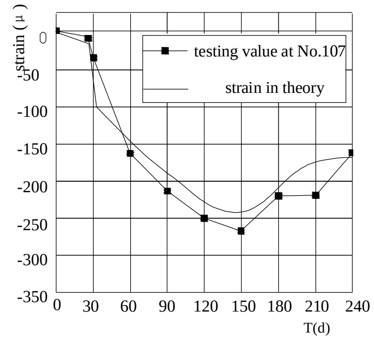
Test value at No.102 and theory



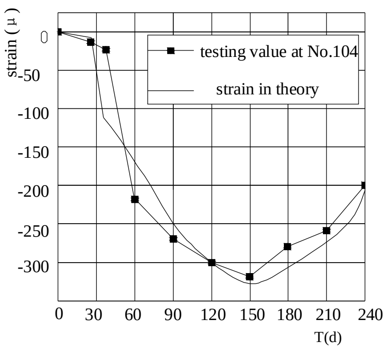
Test value at No.106 and theory



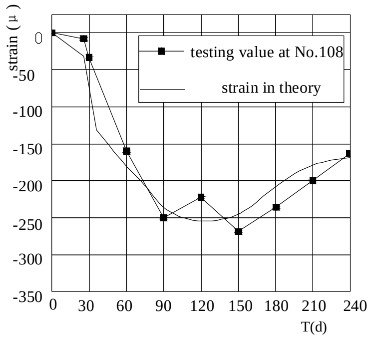
Test value at No.103 and theory



Test value at No.107 and theory



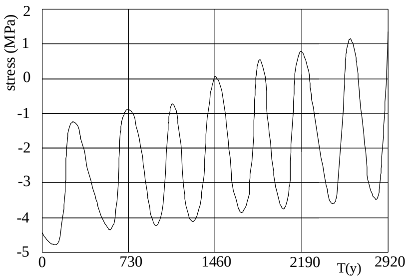
Test value at No.104 and theory



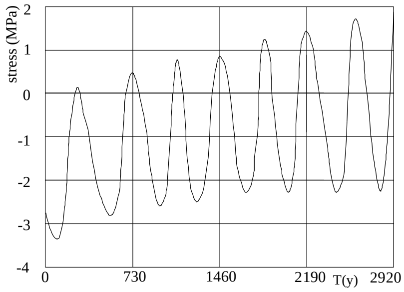
Test value at No.108 and theory

Fig. 3 Curves of test value and theory calculation

The size of temperature stress decides whether crack or not. The stress distribution is side-span less and middle-span big. In Figure 4 the max tensile stress of test point 107 is 1.2MPa, The max tensile stress of test point 108 is 1.7MPa less than tensile strength of C40. It satisfies II-level anti-crack demand.



No.107 stress curve



No.108 stress curve

Fig.4 Test point stress curve

6. CONCLUSION

Season temperature is circled by year that temperature stress must be subsection calculation. Shrinkage is single-way change. Both of them is calculated respectively and then summing. The theory analysis without temperature joint to solve temperature stress is reasonable.

REFERENCES

Zhu Bofang, Thermal Stresses and Temperature Control of Mass Concrete [M]. Beijing: China Electric Power Press, 1998

Teng Zhiming, Basic components of concrete [M]. Beijing: Qinghua University Press, 1987

Guo Zhenhai, Concrete Theory [M]. Beijing: Qinghua University Press, 1999

Z .P. Bazant and Jenn—Chuan Chern. Bayesian statistical prediction of concrete creep and shrinkage. ACI Journal, July—August 1984. 290-308

Zhou Lu, Chen Yongchun [M]. Beijing: China Railway Press, 1994.1

Mamdouh Elbadry, Amin Ghali. Control of Thermal Cracking of Concrete Structures. ACI Journal, July—August 1995. 435-450