Transactions, SMiRT-22
San Francisco, California, USA - August 18-23, 2013
Division IX (include assigned division number from I to X)

ANALYSISOF OF CONCRETE STRAIN LATE DEVELOPMENT FOR CONTAINMENT STRUCTURE

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ABSTRACT

Prestressed concrete containment structure is a special structure form in nuclear power plant, and the main function of containment is to protect the reactor and contain radioactive material produced when LOCA accident happening. In order to evaluate the containment structure, the audio strain gauges should be embedded in the concrete to measure the strain, one aspect, these audio strain gauges would be used to test the strain data in the process of regular strength test of the containment structure, another aspect is to monitor the day-to-day concrete strain to determine the status of the containment structure. The monitoring strain data play a key role to evaluate the status and life extension of the containment structure, and provide valuable data for the researching of prestressed concrete structure. The monitoring data of audio strain gauges have relation with working condition of the containment structure, the long-term stability of strain gauge, shrinkage and creep of concrete, environment of using.

CONCRETE SHRINKAGE, CREEP MODEL AND FORMULA

Several models of concrete creep and shrinkage are ACI209, CEB-FIP MC90, B3, GL2000, SAK, these models have their own characteristics, involving temperature and humidity, scantlings, concrete loading age and other factors. GL2000 model is popular used for predicting the development of concrete strain.

GL2000 Model of Concrete Creep and Shrinkage

Gardner and Locktnan proposed the GL2000 model in 1999. Concrete creep coefficient formula is as follows:

$$\phi_{28} = \phi(t_c)\left[2\frac{(t-t_0)^{0.3}}{(t-t_0)^{0.3}+14} + (\frac{7}{t_o})^{0.5}(\frac{t-t_0}{t-t_0+7})^{0.5} + 2.5(1-1.086h^2)(\frac{t-t_o}{t-t_o+0.15(v/s)^2})^{0.5}\right] \quad (1)$$

$$If\ \ t_o = t_c,\ \phi(t_c) = 1$$

$$If\ \ t_o > t_c,\ \ \phi(t_c) = \left[1-(\frac{t_o-t_c}{t_o-t_c+0.15(v/s)^2})^{0.5}\right]^{0.5}$$

t is the concrete age period (day), t_c is concrete drying instar (day), taking 15 days, t_o is loading of concrete age period (day), taking 365 days, v/s is ratio of volume and surface area, h is relative humidity (decimal).

GL2000 about plain concrete shrinkage formula:

$$\varepsilon_{sh} = \varepsilon_{shu}\beta(h)\beta(t) \tag{2}$$

$$\beta(h) = 1 - 1.18h^4$$

$$\varepsilon_{shu} = 1000k\left[\frac{30}{f_{cm}}\right]^{0.5} \times 10^{-6}$$

$$\beta(t) = \left[\frac{t - t_c}{t - t_c + 0.15(v/s)^2}\right]^{0.5}$$

Which k is relate to the type of cement, ordinary portland cement to take 1, f_{cm} an average concrete cube strength of 28 days.

DEVELOPMENT OF CONCRETE MONITORING STRAIN OF A NUCLEAR POWER PLANT CONTAINMENT

The containment of one nuclear power plate is composed of raft foundation, the cylinder concrete wall, hemispherical dome. The inner diameter of the cylinder is 44.0m, and the thickness of concrete wall is 1.2 m, height 41.6m, the section shape of prestressing concrete containment shown in figure 1. The structure of the containment is prestressed reinforce concrete structure. The mix proportion of cement, sand, gravel, fly ash, water was 1, 1.62, 2.52, 0.14, 0.46, and the 28 days compression strength of concrete was 61.2MPa.

The three orthogonal direction frequency strain gauges have been installed in the concrete at the same position of the wall, and one group of strain gauges in the outside of the wall and another in the inner side of the wall, altogether two groups strain gauges in the same direction along the thickness of concrete wall. These positions of installing strain gauges at the juncture of cylinder wall root and raft foundation, the elevations of 8.7m, 15.4m, 22.2m, 31.2m of cylinder wall, these groups of strains gauges have been distributed in the four directions of the containment structure. And the pt100 had been installed in the position of installing the strain gauges to measure the temperature of concrete.

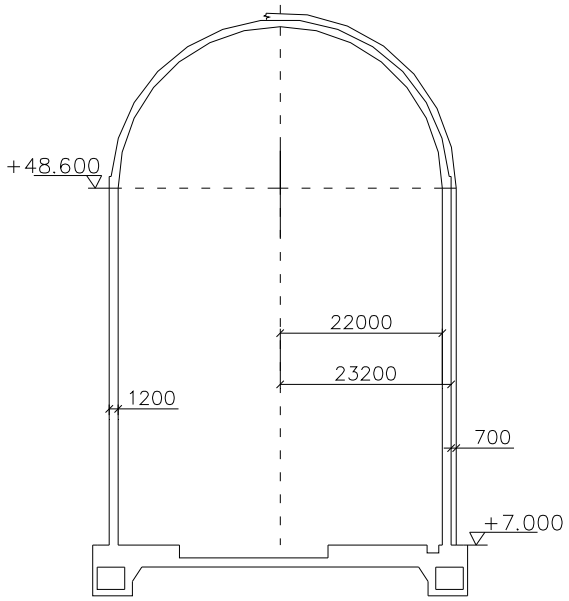

Figure1. Section of concrete containment

Development of Radial (Thickness) Direction Monitoring Strain in Containment Wall

The pre-stress of concrete of containment along vertical and ring directions have been set up through stretching of steel strands distributed in the two directions, and the concrete tensile strain would be produced along the thickness direction (radial), and the data of tensile was very small, especially in the junction field of the buttress of containment and raft foundation, the monitoring data of strain gauges were almost zero during the construction of prestressing. The curves of data of long-term monitoring strain and concrete temperature are shown in figure 2. From the analysis of monitoring data of concrete strain, the concrete tensile strain has changed to compression strain. But, in fact, the stress established in the radial direction of the wall is still tensile. This phenomenon is the result of shrinkage and creep of the concrete. The curve of theory of strain in the figure 2 is got from GL2000 model, including creep and shrinkage of concrete.

The trend of convergence of curve of GL2000 is obvious following the time development, but the actual monitoring curve of strain is still not obvious signs of convergence after 2500 days (about 7 years) of the establishment of prestressing.

The radial tensile strain and long-term monitoring data curve in the other part of containment wall, see figure 3. The original tensile strain changed to compressive strain, and has not convergence trend after 2500 days, and the curve of strain occurs synchronous fluctuation with the temperature variations.

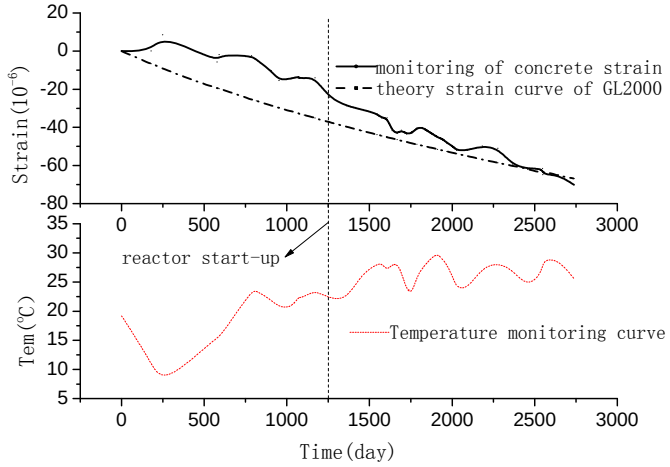

Figure 2. The theory curve and the monitoring curve of concrete strain and temperature (Buttress root)

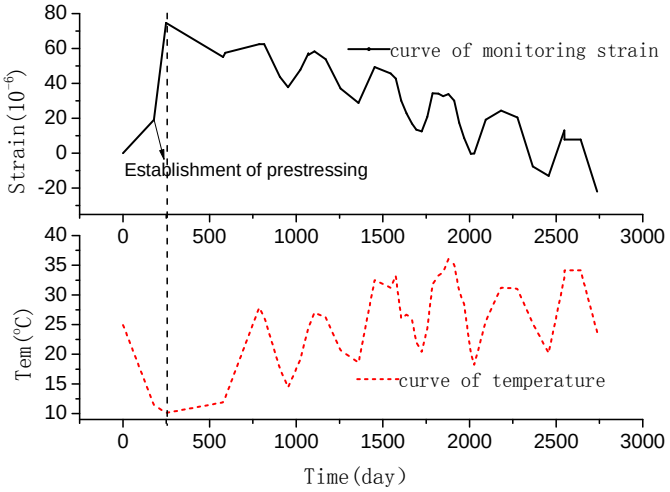

Figure 3. The monitoring curve of concrete radial direction strain and temperature in the wall

Development of Circumferential Strain of Concrete Containment

The value of compressing strain is relative larger than vertical direction on the concrete in the wall of containment. The average monitoring data of concrete strain and temperature of the inner side of wall, see figure 4. And the monitoring curve of outer side of the wall, see figure 5.

In figure 4, monitoring curve of strain and theoretical curve of GL2000, the convergence trend is obvious. But the map of monitoring strain curve in figure 5 deviate from theoretical value, and showed no clear convergence trend. The 6mm thick steel liner was installed on the inner surface of containment to reduce the influence of external environment, and the temperature and humidity of inner space of containment was relatively stable, so the environment of inner side concrete wall was close to the theoretical value, so the monitoring strain curve in the figure 4 is close to the theoretical value.

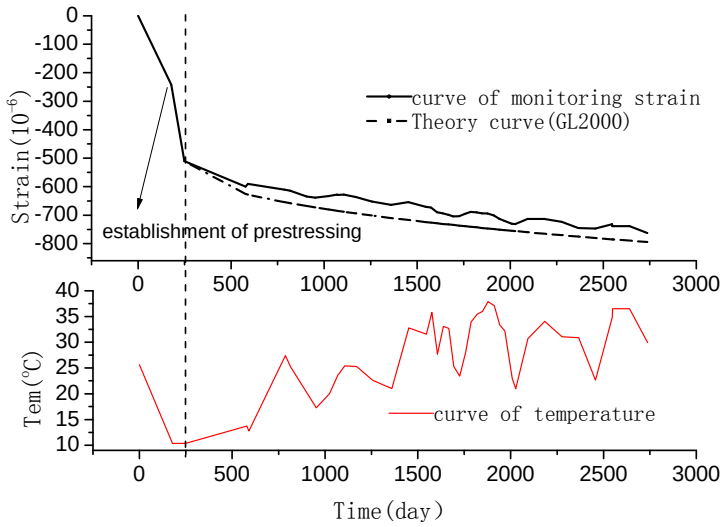

Figure 4. The monitoring curve of tangential direction strain and temperature in the inner side of concrete wall

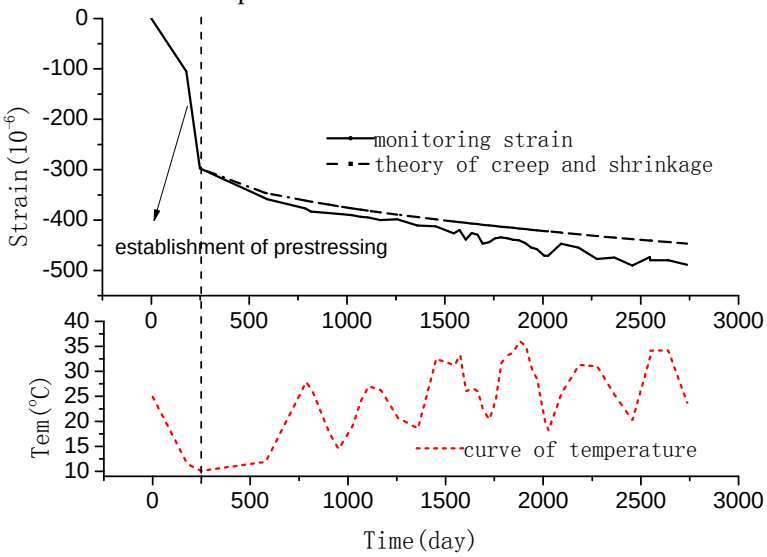

Figure 5. The monitoring curve of tangential direction strain and temperature in the outer side of concrete wall

Development of Vertical Strain of Concrete Containment

The average monitoring strain of cylinder wall containment, inner and outsider lateral acoustic strain gauges vertical strain value curve, see Figure 6, 7. After establishing compressive strain, concrete monitoring value deviate f from the theory of GL2000 curve follow the time away.

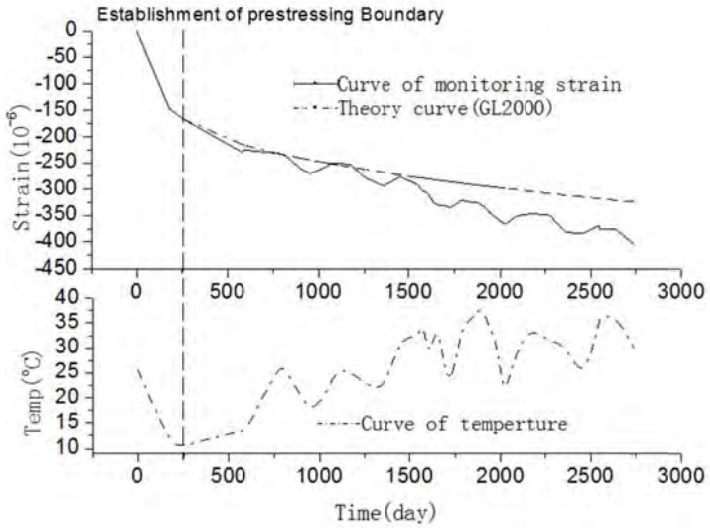

Figure6. The monitoring curve of concrete
vertical direction strain and temperature in the outer side of concrete wall

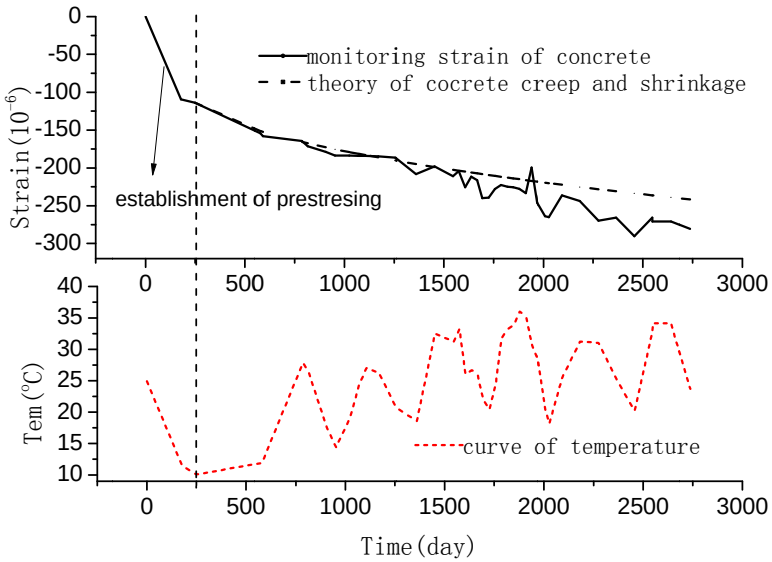

Figure7. The monitoring curve of concrete
vertical direction strain and temperature in the outer side of concrete wall

Brief Summary of Concrete Strain Monitoring Data in Containment

Because of constraint imposing on the containment, monitoring strain of concrete presents regular fluctuation with the change of temperature. Temperature stress and strain causing by temperature of is not recoverable, the residual thermal strain will be produced, with no recovery, accumulating residual strain will make some contribution to the total strain.

With the Long-term using, these audio strain gauges having embedded in the concrete, there are some drift, because of the method of machining process and material properties of sensor. The occlusal pattern of steel string and anchoring disc in the strain gauge is important, because the steel string will produce a certain slipping from the anchoring under the long-term using. These phenomenon will leads to lower frequency of the steel string. The reduce of reading value of sensor will result compression strain to

increase, even more than the true strain because of concrete shrinkage, creep, temperature accumulation generated value, conceal the truth.

The empirical formula and prediction model of concrete shrinkage and creep, were popularly got basing on laboratory conditions (constant temperature and humidity, small size of component), and these conditions have difference with the actual environment, and certain specific conditions in practical projects may guide the development of concrete shrinkage and creep. So the job of researching and measuring for the shrinkage and creep of concrete is needed.

Containment is a prestressed concrete structure, and the concrete material has nonlinear property under the temperature and stress. Along with the time development, shrinkage and creep of concrete, relaxation of prestressed reinforcement, would cause stress redistribution on the concrete. Seasonal change of air temperature, concrete shrinkage, creep and prestress steel relaxation and differences between sensor and concrete thermal parameters, together, result the development of the monitoring compressing strain.

CONCLUSION

There is still a large development of concrete shrinkage and creep after seven years in Large size prestressed concrete members, is not negligible. The actual monitoring data deviates from the theoretical value.

Temperature stress and strain caused by temperature changes have certain amount of unrecoverable, and residual temperature strain is to make some contribution to concrete strain the total.

The predictive models of concrete creep and shrinkage are based on idealized conditions, under the conditions of lab, there are great differences with the actual environment. And the influencing factors are not comprehensive, even some special factors are ignored.

These predictive models need further researching and revising, and should base on the monitoring data more than 3 years.

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