Prestress Technology and Crack Control of Super-Long Concrete Structure

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Abstract. This paper summarizes the causes of cracks in super-long concrete structures. Based on this, advantages of the prestress technology of super-long concrete structure are explained. On the basis of the summary, the prestress technology is the most effective measure. In this paper, the temperature stress and restraint stress are introduced, and the prestress technology is explained, which is beneficial to the application and crack control of super-long concrete structure.

1. Introduction
Concrete structure is an important part of civil engineering. Its safety and durability to a certain extent affect the safety and stability of buildings and structures, and also affect the production and life of the public. With the development of modern architecture of multi-functional, in more and more buildings, the public not only pursues the integrity of the use function and structure, but also pays more attention to the effect of the plane and facade of the building. Because expansion joints affect the use function and aesthetics of buildings and structures to a certain extent, more and more buildings and structures reduce the setting of expansion joints, and even some buildings and structures do not set expansion joints. Therefore, some buildings and structures need to be designed as super-long concrete structure. This kind of structural design meets the needs of architectural design. Because the super-long concrete structure is constrained by the temperature change and structural members, the structure itself can't contract freely, and the structure produces large temperature stress and constraint stress. There are serious temperature shrinkage cracks at super-long concrete structures[1]. The safety, stability and service performance of super-long concrete structure are seriously affected. Crack control of super-long concrete structure has become a quality problem that construction enterprises pay more and more attention to. Therefore, It is imperative to control the crack at super-long concrete structure. The crack control of super-long concrete structure must be achieved by adopting reasonable design.

2. Causes and treatment of cracks at super-long concrete structure

2.1. Causes of cracks at super-long concrete structure
According to Code for design of concrete structures (GB 50010-2010), when the length exceeds 55 m, expansion joints are required in the code, but the concrete structure without permanent expansion joints are super-long concrete structure. From the stress point of view, according to the Code for design of prestressed concrete structures (JGJ 369-2016), when the length is not more than 55 m, due to the strong constraint of the structure, large temperature difference, large concrete shrinkage and other reasons, the concrete structure whose component stress exceeds the limit value is super-long concrete structure.
At present, many construction projects will be applied to super-long concrete structure. In the process of construction and use, cracks are very common. The structural temperature difference and concrete shrinkage of super-long concrete structure are relatively large. The restriction of structural members of super-long concrete structure is also large. Because the building is in the natural environment for a long time, the super-long concrete structure will be affected by various adverse natural factors. These influences run through the whole process of construction and operation. The weather conditions, the temperature difference between day and night, and the seasonal variation will have more or less influence on the building. In other words, buildings will be affected by temperature changes. Due to the influence of temperature change, the super-long concrete structure will produce relatively free longitudinal stress deformation in the wall, column and other parts. However, when the transverse structure such as beam and slab deforms, the transverse structure will be constrained by some vertical structural members, which leads to the internal stress of the structure. Under the action of concrete shrinkage and environmental temperature change, the super-long concrete structure will produce greater restraint stress and temperature stress. Under the action of double stress, the temperature stress will cause certain tension to the concrete structure. There is a large tensile stress in the concrete. With the gradual increase of temperature deformation, the internal binding force of the structure shows a gradual upward trend. When the tensile stress exceeds the tensile strength of concrete, the concrete will produce cracks. That is to say, the main causes of cracks in super-long concrete structure are temperature and restraint [2].

The cracks of super-long concrete structure will affect the durability and normal use of the building. The cracks of super-long concrete structure are divided into temperature cracks and shrinkage cracks.

- **Temperature cracks.** The main reason of temperature cracks is the influence of internal and external temperature difference of concrete, and the internal stress caused the tearing reaction of concrete.
- **Shrinkage cracks.** Shrinkage cracks is the crack of concrete in the process of shrinkage.

Once the temperature cracks and shrinkage cracks appear in super-long concrete structure, the stability and durability of buildings and structures will be seriously threatened. Therefore, it is necessary to study the confinement effect and temperature effect [3].

2.2. **Treatment of cracks at super-long concrete structure**

The most economical, reasonable, safe and reliable treatment measure for the cracks of super-long concrete structure is to adopt prestress technology in the super-long concrete structure.

The application of prestressed technology in super long concrete structure has the following advantages.

- The prestressing stress established by prestress technology can completely or partially offset the tensile stress caused by concrete shrinkage and temperature change [4].
- The prestress technology can exert a certain amount of pressure on the super-long concrete structure before it is stressed. The stiffness of super-long concrete structure can be improved.
- The tensile stress caused by temperature effect and restraint effect will be reduced. In addition, prestress technology can reduce the setting of expansion joint and post cast strip.
- The prestress technology can also delay the cracking time and area of super-long concrete structure. Therefore, in order to reduce the cracks of super-long concrete structure, avoid the loss of prestress and improve the effect of prestress, it is necessary to explain the prestressed design of concrete.

3. **Design of prestress of super-long concrete structure**

The vertical members of super-long concrete structure can not only bear the gravity and load, but also provide certain lateral stiffness for the structure itself. At the same time of providing lateral stiffness for the structure itself, the vertical members will also form a certain constraint on the transverse members in the super-long concrete structure. Under this kind of constraint, the temperature deformation of super-long concrete structure will be limited to some extent. At the same time, the restraint also has a certain impact on the effective stress established by the prestress technology [5]. Therefore, the design of prestress is described below.
For regular single span or multi span frame structures, the constraint coefficient $\eta$ can be expressed as [5]:

$$\eta = \sum_{i=1}^{m} \frac{x_i D_{ci}}{E_{gi} A_{gi} + \sum_{k=1}^{m} \frac{x_i^2}{x_k} D_{ck}}$$

(1)

$x_i$: distance from the $i$-th spans to the deformation fixed point.  
$D_{ci}$: lateral stiffness of the $i$-th column.  
$E_{gi} A_{gi}$: tension and compression rigidity of beam members.  
$x_k$: distance from the $k$-th spans to the deformation fixed point.  
$m$: the number of spans of half structure of one sides with the fixed point of frame deformation.  
$D_{ck}$: lateral stiffness of the $k$-th column.

For continuous constrained structures, the constraint coefficient $\eta$ can be expressed as [5]:

$$\eta = 1 - \frac{2}{e^{\beta L} + e^{-\beta L}}$$

(2)

$$\beta = \sqrt{K / E_{gi} A_{gi}}$$

(3)

$K$: Stiffness per unit length.  
$L$: The distance from the end of the structure to the deformation fixed point.

For single span frame, multi span frame and continuous constrained rigid structure, the temperature effect $F_T$ at the fixed point of structural deformation can be expressed as [5]: 

$$F_T = \alpha T E_{gi} A_{gi} \eta$$

(4)

The relationship between the effective prestress $F_p$ of the fixed point of structural deformation and the applied prestress $N_p$ is [5]:

$$F_p = N_p (1 - \eta)$$

(5)

For more specific meanings of formula symbols, please refer to literature[5].

4. Other supplementary measures

In order to control the cracks of super-long concrete structure better, some other measures should be adopted according to the principle of "resistance" and "release".

- "Resistance" measures. During construction, construction enterprises can take measures such as using high-performance concrete, adding expansion agent, using fiber concrete and increasing reinforcement ratio.
- "Release" measures. Construction enterprises can choose to set up sliding bearing or isolation layer, adopt alternative bay construction method.

5. Concluding remarks

The application of super-long concrete structure in various engineering projects is very common. Although super-long concrete structure has obvious advantages in many aspects compared with ordinary concrete structure. However, super-long concrete structure is also easily affected by temperature stress and restraint stress. The structure will face a greater risk of cracking. In order to control the cracks caused by temperature stress and restraint stress, the establishment of prestress of super-long concrete structure can greatly improve the construction quality of super-long concrete structure. The deformation of super-long concrete structure caused by temperature stress and restraint stress will also be relieved. The measures of "resistance" and "release" are supplemented. The temperature cracks of super-long concrete structure will also be improved. It has a certain improving on the durability and function of super-long concrete structure.
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References
[1] ZHENG, C., ZHANG, T., XU, W., et al. (2019) Temperature change analysis upper super-long concrete structure. Journal of Qingdao University of Technology., 40: 30-37.
[2] FENG, T., ZHANG, T., XU, W., et al. (2019) Study on and analysis of shrinkage stress test of super-long concrete floor slab. Journal of Qingdao University of Technology., 40: 18-23.
[3] LU, B., LI, J., MAO, C., et al. (2017) Analysis and Engineering Practice of Temperature-effects on Overlong Concrete Structures. Structural Engineers., 33: 21-26.
[4] Dong Y. (2011) Application of pre-stress technology in crack control of overlong concrete structure. Building Structure., 41: 1031-1034.
[5] Xiong, X., Xiang, R., Wang, J., et al. (2018) Prestress design of super-long concrete structure. Building Structure., 48: 5-15.