Self Compacting Plain Concrete for Underground Substations Construction Technology Research

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Abstract. In response to the L-shaped irregular shape, dense steel bars, and high requirements for the appearance of clean water in a certain underground substation, the surface appearance quality of the concrete structure is required to be high. Therefore, the use of self compacting clean water concrete construction technology is comprehensively considered. This article compares and studies the selection of concrete materials and coarse aggregate requirements through on-site sample tests, controls the water cement ratio and sand ratio, and conducts reasonable mix design. The selection of mirror red templates and the treatment of template joints ensure the quality of the formation of plain concrete, enabling the application of self compacting plain concrete construction technology in underground substations and providing reference experience for subsequent underground substation projects.

Keywords: Underground substation, Plain concrete, Self compacting, Mirror red template

1. Introduction

The as-cast concrete structure is formed in one go, without the need for decorative painting on the surface, which can reduce on-site construction processes and maintain good concrete surface texture. It is widely used in bridges, airports, industrial and civil buildings [1-2]. When pouring self compacting fair faced concrete, there is no need for vibration. It not only has the advantages of high fluidity of self compacting concrete, improving work efficiency, reducing manpower and construction equipment usage, and meeting and improving the pouring quality of complex structures, but also has the advantages of excellent surface appearance quality of fair faced concrete and no need for decoration [3-4].

A certain underground substation is located in Xiong'an New District. It adopts a three story main shear wall structure underground and a one story auxiliary structure above ground, and all electrical equipment is placed on the underground structural layer. The above ground structure is designed with a power element shape, known as the "wings of power". The underground structure has a deep burial depth, a large pouring volume, and an overall L-shaped shape with dense internal steel bars. According to the design requirements, the entire structure is made of plain concrete, and the surface of the structure must have good visual molding quality. Taking into account the structural characteristics of underground substations and considering the use of self compacting plain concrete construction technology, it not only has good self compacting characteristics, but also requires simple auxiliary vibration, reducing vibration personnel, saving labor costs and improving the construction environment, and achieving excellent surface quality of plain concrete. This article summarizes and analyzes the application of self compacting fair faced concrete in the construction process of underground substations, which is of great significance for the subsequent summary and promotion of technology in underground substations and similar power transmission and transformation projects.

2. Project Overview

A certain underground substation is located within the scope of the comprehensive energy station in Community A of Rongdong District, Xiong'an New Area. The west, south, and east sides of the plot are all planned municipal roads, while the north side of the plot is a park green space. The entire substation is located on the east and south sides of the plot, in an L-shaped layout. It is a sunken courtyard style substation with three underground floors and one above ground floor, with a building area of 7235m2 and a buried depth of 16.9m. The three underground floors are shear wall structures, made of C35P10 concrete. The main structure of the substation has a waterproof grade of one, and the maximum thickness of the outer wall is 900mm. This substation is the first underground substation of the main grid in Xiong'an, which is of milestone significance for the construction of the Xiong'an power grid and the development of the Xiong'an New Area. To this end, the first fully plain concrete structure substation will be built. To meet the requirements for the quality of building entity formation and appearance, the entire structure will be poured with self compacting plain concrete and formed in one go.

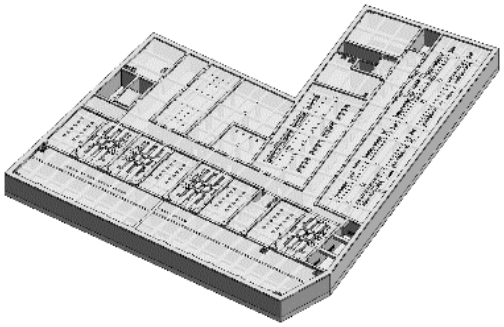


Figure 1. Structural Model Diagram

3. Analysis of Two Difficulties

The density of steel bars is high. The overall structure of the underground substation is arranged in an L-shaped irregular shape, with a thickness of 900mm on the outer wall C32@100 Double layered bidirectional steel bars are arranged with narrow spacing between bars, and Y-shaped and V-shaped columns are used locally, with consideration given to stirrups and tie bars, resulting in excessive steel bar density (as shown in Figure 2) and affecting the quality of concrete pouring.

There are many reserved holes. Due to the deep burial depth of the underground substation structure, and according to the overall layout requirements of electrical equipment, there are many openings and openings in the walls and floors, with over 400 single-layer openings and over 800 overall building openings. There are more than 30 stacked holes. Ventilation and ventilation in underground substations are important guarantees for ensuring the safe operation of electrical equipment. Electrical equipment rooms are connected through cables, resulting in more than 100 openings with dimensions greater than 800 on the building wall. As a result, there are many hidden beams, columns, and connecting beams in the shear wall, with 620 buried pipes. Any omission will damage the requirements of the plain concrete process.

A large amount of pouring at one time. The pouring volume of concrete for the entire station structure reaches 10000m3, and only 3100m3 of concrete is poured for the underground three story structure. The height of the sunken courtyard wall is 10.6m and the length is 54.4m, which requires high pouring operations and uninterrupted operation. There should be no cold joints or construction joints that affect the appearance quality.

To solve practical engineering problems and achieve good surface quality of structural water, the solution ideas are as follows:

(1) Raw materials: It is necessary to ensure that the concrete has high fluidity and filling ability with self compacting performance, and to ensure dense pouring of steel bars and reserved holes. At

the same time, it is necessary to ensure the waterproof effect of P10 and meet the apparent color requirements of plain concrete.

(2) Mix ratio: By selecting reasonable material dosage, water cement ratio, and sand ratio through sample testing, it can meet the self flowing compactness and ensure the quality of plain concrete pouring.

(3) Template selection: By comparing the effectiveness of different templates and the supporting process through template tests, it is ensured that the finished concrete is formed in one go and the surface is optimized.

(4) Concrete pouring control: Strict quality control is carried out from the acceptance of raw materials entering the site, concrete pouring, curing, and other processes to ensure the quality of concrete pouring and curing in place.

4. Raw Materials and Mix Design

4.1. Selection of raw materials

To ensure the high flow and self compacting performance of concrete, the appearance quality of non decorative clean water after concrete formation, and to meet the waterproof requirements of concrete, the selection of raw materials should be as consistent as possible to ensure the same batch and stable performance. The cement is produced by the same manufacturer, with a grade of P.O42.5, and its physical properties should meet the requirements of the specifications. Optimizing polycarboxylic acid water reducing agent to improve the workability of concrete, and adding air entraining agent to control the internal bubbles of self compacting plain concrete. Medium sand is selected, with a fineness modulus of around 2.5-2.8, a mud content of ≤ 1.5%, and a mud block content of ≤ 0.5%. The coarse aggregate should be well graded, using self compacting concrete special crushed stones with uniform color and consistent color. The mud content in the crushed stones should be ≤ 0.8%, the mud block content should be ≤ 0.1%, and the needle like content should be ≤ 5%.

The key to achieving high flow and self compacting performance of self compacting plain concrete is to control the grading of coarse aggregate. After on-site sample testing and analysis, it was found that using crushed stone with a specification of 5-16mm and good grading as coarse aggregate, the mixture has the best flowability and self compacting performance, making it suitable for self compacting plain concrete coarse aggregate. The comparative analysis results are shown in Figure 2 and Table 1.

Table 1. Table Type Styles

Gravel specifications	Slump spread/mm	28d compressive strength/MPa
5-20mm	five hundred and fifty	thirty-eight point five
2-16mm	six hundred and fifty	thirty-seven point two



a. Measurement of slump of 5-20mm crushed stone mixture



a. Measurement of slump of 2-16mm crushed stone mixture

Figure 2. Slump measurement diagram of different specifications of crushed stone mixtures

4.2. Water cement ratio

To ensure that concrete has excellent high flow self compaction and waterproof performance, it is fully filled into the interior of each concrete component through gravity self flow, and there are no bubbles or other phenomena after forming. Sample tests are compared using different water cement ratios, and the analysis is shown in Table 2.

From the experimental results, it can be seen that when the water cement ratio is small (0.4), the concrete mixture is too viscous, which is not conducive to the flow of concrete, nor is it conducive to the exhaust of the mixture, affecting its self compacting performance. When the water cement ratio is high (0.46), the fluidity of the concrete mixture is too high, and excessive bleeding is prone to generate a large amount of water. The surface is prone to a large number of small bubbles, which affects the appearance of the concrete. When the water cement ratio is 0.43, the mixture has good flowability and can be fully filled into the interior of the structure, with good self compacting performance. At the same time, the concrete surface is smooth and free of bubbles after formwork removal, and the apparent quality is good.

Table 2. Comparison of concrete performance tests with different water cement ratios

Water cement ratio	*slump flow*	*28d compressive strength*	*Mix state*
zero point four	five hundred and fifty	thirty-eight point two	The mixture is relatively viscous and has poor fluidity. The steel bars have poor passability, and there is mold sticking on the surface of the concrete after forming.
zero point four three	seven hundred	thirty-seven point four	The mixture has good fluidity and self compacting performance, and the surface of the concrete after forming is smooth without obvious bubbles.
zero point four six	eight hundred	thirty-seven point one	The fluidity of the mixture is too high, and there are many small bubbles on the surface of the concrete after forming.

4.3. Sand rate

The sand ratio is one of the key factors to ensure the high flow and self compaction performance and good apparent quality of self compacting concrete, and different sand ratios cause inconsistent flow performance of concrete mixtures. Through on-site testing and comparison, when the sand content is 40%, the concrete mixture has good flowability and self compacting performance, and the apparent quality of the concrete after forming is good. When the sand content is too high or too small, the fluidity of the concrete mixture is not good, which is unfavorable for the self compaction of the concrete and the appearance quality of clean water. The test results are shown in Table 3.

Table 3. Comparison of concrete performance tests with different water cement ratios

Sand rate	*slump flow*	*28d compressive strength*	*Mix state*
zero point four	six hundred	thirty-nine point one	The mixing flow rate is relatively small and viscous, and bubbles are not easily squeezed out.
zero point four three	six hundred and fifty	thirty-eight point three	The self compacting performance is good, and there are no obvious bubbles after the concrete is formed.
zero point four six	seven hundred and fifty	thirty-seven point six	The mixing speed is good, and the surface of the concrete is textured.

4.4. Mix ratio

Through the selection of raw materials and comparison of key parameters of the mix ratio, on-site tests were conducted to obtain a suitable C35 self compacting plain concrete mix ratio for the underground substation. The test results are shown in Table 4.

Table 4. Comparison of concrete performance tests with different water cement ratios

Water cement ratio	*Sand rate/%*	*Cementitious material/kg*	*Fly ash content/%*
zero point four three	forty	four hundred and twenty	twenty-one

5. Template selection

5.1. Template selection

The selection of formwork is one of the key factors for controlling the surface effect of fair faced concrete. This project compares the appearance quality of concrete using polymer templates, clear water black templates, and mirror red templates. The test results are shown in Figure 3 and Figure 4.

Through comparative analysis, it can be concluded that using polymer templates has high strength, high stiffness, and fast assembly speed, which can greatly improve construction efficiency. However, the template has large staggered joints, and the surface is prone to sticking, without any abnormal parts, which cannot achieve a clear water effect. The strength of the clear water black template is relatively low, and the surface is prone to produce textures that affect the appearance effect of concrete molding. The mirror red template has high strength, thick plastic plating on the surface, good concrete forming quality, smooth surface, no obvious bubbles, and can achieve a good clean water appearance effect.



Figure 3. Comparison of Different Templates



Figure 4. Effect of using different templates for concrete

5.2. Template splicing treatment

The joint of formwork is a difficult point in the control of clean water shear walls, and the unsatisfactory joint treatment directly affects the appearance quality of concrete after formwork removal. This project combines the mirror red template and on-site sample test analysis. The internal and external corner joints are pasted with the same template wide sea cotton strip, and compressed and compacted with the template. The joint between the plates is fixed on the outer side of the template using riding nails (as shown in Figure 5) to ensure seamless splicing and secure fixation between the templates.

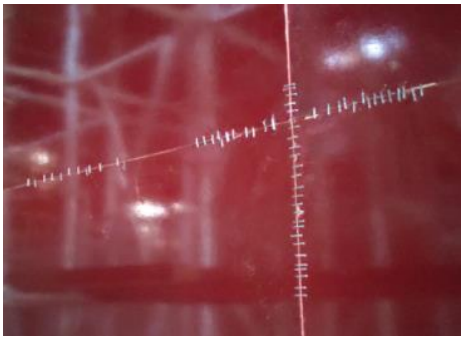


Figure 5. Template Splicing Processing Diagram

6. Concrete pouring and curing

6.1. Concrete pouring

The pouring volume of concrete for each of the three underground floors of this project is about 3000 cubic meters. The pouring volume is relatively large and the wall is high. During pouring, it is necessary to pour in layers, controlled at around 0.5m, to ensure high fluidity and self compaction of the concrete, and to facilitate the discharge of bubbles. Use a vibrating rod to assist in vibration, but the vibration time should not be too long to avoid affecting the self compacting performance of the concrete. Fixed point vibration can be used, with a time control of about 15 seconds. The insertion of the vibrating rod should not be too deep, and the main focus should be on controlling surface bubbles. When pouring the wall opening, use a small vibrator to vibrate on the outside of the template to strengthen the compactness of the concrete at the bottom of the opening. During pouring, continuous pouring should be carried out at once, without cold joints that may affect the waterproof performance of the concrete.

6.2. Concrete curing

The curing stage of concrete is equally important. The demolding time of self compacting fair faced concrete is extended by 1-2 days compared to conventional processes. Immediately after demolding, a film is used to cover or spray water for curing, controlling the humidity of the concrete surface and avoiding cracks caused by rapid water loss and easy drying of the concrete surface. During the curing process, measures should be taken to prevent surface contamination of concrete and ensure the appearance quality of fair faced concrete.

7. Conclusion

The control and mix ratio of raw materials, applicability of templates, and concrete pouring and maintenance are key control factors for achieving the ideal surface quality effect and meeting the waterproof protection level of self compacting plain concrete in underground substations. The selection of raw materials, especially coarse aggregates, must use high-quality materials, fully considering the particle size distribution of coarse aggregates, cement hydration heat, concrete mix ratio, and good additives, which are conditions to ensure the self compacting performance of concrete and the appearance effect of fair faced concrete. The key to the mix design of self compacting fair faced concrete is to control the water cement ratio and sand ratio. The correct selection of templates, the configuration of auxiliary vibrators, and the strengthening of concrete curing are key control measures to ensure that self compacting fair faced concrete achieves high-quality surface quality effects.

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