UHPC-Annular Reinforcement Wet Joint Performance Analysis and Concrete Strength Influence Research

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Abstract. Based on the Shanghai Road High-speed Railway Station Connection Line Reconstruction Project in Suqian City, this paper firstly introduces the broad application and development prospects of prefabricated small and medium-span bridges, and explains the purpose of this paper; secondly, it introduces UHPC-ring steel bar wet, the structural form of the joint, and the elastoplastic analysis of it, and the comparison of the original plan and the UHPC-ring steel wet joint plan; finally, the law of the influence of the strength of the joint concrete on the wet joint performance is carried out. the study. The research results show that: UHPC-annular steel bar wet joint has good mechanical properties. As the strength of post-poured concrete at the joint increases, the ultimate bearing capacity of the structure, the bearing capacity when the steel bar yields, and the bearing capacity when cracking are all increased accordingly. The change in the bearing capacity corresponding to cracking is the most obvious, and the increase in the yield strength and ultimate bearing capacity of the steel bar is not very obvious.

1. Introduction
In the development process of bridge construction in China, small and medium-span prefabricated bridges have an indispensable position. Vigorously develop small and medium-span prefabricated bridges, which will improve bridge construction quality, speed up bridge construction, and improve bridge construction technology and industrialized construction level. It is of great significance to reduce the labor intensity of workers, reduce the cost of bridge construction, and promote environmental protection and resource conservation. At present, prefabricated bridges, like conventional bridges, mainly have three forms: steel beams, steel-concrete composite beams and concrete. Among them, the prefabricated bridge decks of fabricated concrete beams and matched steel-concrete composite beams need to be connected by cast-in-place wet joints. However, a large number of engineering practices show that the existing prefabricated bridge structures (mainly for concrete and steel-concrete composite beams) still have the following main technical bottlenecks:

(1) The age of the precast part of the main girder (precast bridge deck with steel-concrete composite beam) and the cast-in-situ wet joint part of the concrete are different, resulting in inconsistent shrinkage and creep effects\cite{1}.

(2) Due to the small amount of concrete and the small spacing between steel bars, the post-cast wet
joints caused insufficient compaction of concrete, and the treatment of new and old concrete interfaces was not strict, making the construction quality less than required[2].

(3) Conventional wet joints have a large number of steel bars that need to be welded on site, resulting in a large increase in the amount of on-site construction, and the lower steel bars are not easy to weld, and its welding quality is not easy to guarantee.

(4) Because wet joints are the weak link in bridge deck construction, wet joints often initially produce partial cracks. However, as the water seepage leads to corrosion of steel bars and the alternating cycle of repeated wheel loads, the cracks of wet joints will expand into long cracks. This will affect the lateral force distribution of the main girder structure and even form a state of force on the veneer[3].

Generally speaking, the transverse connection nodes (wet joints) are the weak link of prefabricated concrete and steel-concrete composite beams. Once cracks and other diseases occur due to complex forces and other factors, it is easy to cause stress on the single beam and leakage. Technical problems of beam bearing performance and durability. It can be seen that the wet joint (lateral connection) between assembled bridges is an important node to ensure the overall performance of the bridge structure, and has a vital impact on the overall bearing capacity of the bridge.

UHPC ultra-high-performance concrete is a new type of high-performance cement-based composite material. Compared with ordinary concrete, it has excellent characteristics in terms of physical and mechanical properties such as strength, toughness and durability. Combining the excellent mechanical properties of UHPC with the key nodes of the prefabricated structure, the strength of the node is higher than that of the base material, and a feasible idea is provided for solving the technical problem of the weak link of the horizontal connection node (wet joint)[4–6].

This article takes the Shanghai Road High-speed Railway Station Connection Line Reconstruction Project in Suqian City as the research background project. The scope of the project starts at the intersection of Shanghai Road and Minbian Road in the west, and ends at the intersection of Naner Road and South Huanghe Road in the east. The total length of the project route is about 2.8km, and the width of the red line is 43m~67m.

2. UHPC-annular reinforcement wet joint performance analysis
The finite element analysis in this chapter uses ABAQUS software to perform elasto-plastic analysis of the UHPC-annular steel bar wet joint. The concrete uses the ABAQUS CDP model, which is the concrete plastic damage model, and the steel bar adopts a completely elasto-plastic model that does not consider the stress strengthening effect of the steel bar.

2.1. Material constitutive relationship
At present, a large number of scholars at home and abroad have carried out corresponding researches on the constitutive relationship of UHPC (Ultra High Performance Concrete) materials, and have obtained many research results. However, there is still no such thing as a stress-strain curve in the design code of concrete structures at home and abroad. A unified standard that can be used as a reference.

In this paper, the elastic-plastic analysis constitutive relationship of UHPC refers to the relevant regulations in the concrete structure design specification. The tension-compression constitutive relationship of ultra-high performance concrete UHPC120 and ordinary concrete C50 is shown in the figure below.
2.2. UHPC- annular reinforcement wet joint Design
The width is 60cm, the concrete adopts C50 concrete with the same label as the main beam, and the steel bars are connected in the form of welding by ring steel bars. This kind of wet joint has a large width, a large amount of on-site construction, and the steel bars are easy to form dislocations and cannot be effectively welded. UHPC- annular reinforcement wet joint are used, as shown in the figure below, which can not only reduce the width of the wet joints, but also increase the wetness. The strength of the joints and the use of lapped steel bars facilitate construction without the problem that the steel bars in the original plan cannot be effectively welded.

2.3. Calculation model
The finite element analysis model is 2m in length, 0.6m in width (in the bridge direction), and 0.2m in thickness; the width of the middle joint is 30cm, the material is UHPC 120, the steel bar spacing is 10cm, the diameter is 12mm, and the applied load is 100kN. The loading method is four-point bending loading, the bottom support is located at 10cm at the beam end, and the upper loading point is located at 70cm at the beam end. The overall finite element analysis model and the internal reinforcement finite element analysis model are shown in the following figure.

Figure 1 Compressed constitutive relationship  Figure 2 Tension constitutive relation

Figure 3 UHPC- annular reinforcement wet joint  Figure 4 Reinforcement diagram

Figure 5 Finite element model
2.4. Result analysis
This chapter selects the original plan and the UHPC plan for comparative analysis, and extracts the concrete stress and the plastic damage of the concrete to compare and analyze the mechanical properties of the original plan wet joint and UHPC-ring steel wet joint. The analysis results of the two schemes are shown in the following figures. Figures 6 to 8 are the results of the reinforcement stress, concrete stress, and concrete damage of the UHPC-annular steel wet joint; Figures 9 and 10 are the concrete stress and concrete damage results of the original plan of the wet joint.

![Figure 6 Rebar stress calculation results](image1)

![Figure 7 UHPC joint model concrete stress](image2)

![Figure 8 UHPC joint model concrete damage](image3)

![Figure 9 C50 joint model concrete stress](image4)

![Figure 10 C50 joint model concrete damage](image5)

From the calculation results, it can be seen that when the concrete in the tension zone of the C50 wet joint is loaded with 30kN, its plastic damage has already occurred, while the UHPC concrete has no damage to the UHPC part until 60kN.

Through comparison, it can be found that compared with C50 wet joints, UHPC wet joints have a 1.9 times higher cracking damage load and a 1.8 times higher load-bearing capacity at failure, indicating that UHPC wet joints can achieve good results.

3. Seismic performance analysis
From the research results in the previous chapter, it can be seen that the use of UHPC in the joint concrete greatly improves the mechanical properties of the joint. In order to better study the influence of the strength of the joint concrete on the performance of the wet joint, Three working conditions of joint concrete cube compressive strength of 50Mpa, 80Mpa, 100Mpa, and 120Mpa (UHPC120) were
selected for corresponding analysis.

Extract the corresponding load when cracking, the corresponding load when the steel bar yields, and the ultimate bearing capacity load under the above four working conditions. In this special note, the corresponding load when cracking in this article means that the post-wet joint position concrete reaches its limit. The load when the corresponding axial tensile strength standard value; the steel bar yield load is the load when the steel bar in the entire structure model first reaches 210MPa; the ultimate load refers to the precast part of the concrete (the concrete at the non-post-cast wet joint position) reaches the C50 axis. The corresponding load is the standard value of compressive strength. This is because the failure of the entire model, except for C50, is the first to occur in the precast part of the concrete. The results of the analysis are shown in the table and figure below.

Table 1 Analysis result of strength influence on joint performance

| Working conditions | Ultimate load/KN | Rebar yield load/KN | Cracking load/KN |
|--------------------|------------------|--------------------|------------------|
| C50                | 70.2             | 49.3               | 26.7             |
| C80                | 72.8             | 51.5               | 34.3             |
| UHPC100            | 72.9             | 53.1               | 47.0             |
| UHPC120            | 73.0             | 53.5               | 56.6             |

Figure 11. Analysis result of strength influence on joint performance

It can be seen from the figure that as the strength of the post-pouring concrete at the joint increases, the ultimate bearing capacity of the structure, the bearing capacity when the steel bar yields, and the bearing capacity when cracking are all increased accordingly. Among them, the cracking load changes most obviously, because the cracking load of this part of the concrete is directly related to its own strength; the increase in the yield strength of the steel bar and the ultimate load is not very obvious, because these two indicators are related to the strength of the joint part of the post-pouring concrete. Not directly related. The results show to a certain extent that the improvement of the concrete strength of the post-casting joints has a significant improvement in the performance of the joints in the province, but the performance improvement of the entire structure (including the original prefabricated parts) is not very obvious.

4. Conclusion
Based on the connection line reconstruction project of Shanghai Road High-speed Railway Station in Suqian City, this paper firstly introduces the broad application and development prospects of prefabricated small and medium-span bridges, and explains the purpose of this paper; secondly, it introduces UHPC-ring steel bar wet, the structural form of the joint, and the elastic-plastic analysis on it, and the comparison of the original plan and the UHPC-ring steel wet joint plan; finally, the law of
the influence of the strength of the joint concrete on the wet joint performance is carried out. The study.

The main research conclusions are as follows:

(1) The prefabricated small and medium-span bridges have broad development and application prospects, but there are also transverse connection nodes (wet joints) which are the weak links of prefabricated concrete and steel-concrete composite beams. Once they occur due to complex forces and other factors Diseases such as cracks can easily lead to the stress on the single beam and the occurrence of technical problems that affect the bearing performance and durability of the main beam, such as leakage.

(2) Through comparison, it can be found that the cracking damage load of UHPC-annular steel bar wet joints is 1.9 times higher than that of C50 wet joints, and the load-bearing capacity at failure is increased by 1.8 times, shows that the use of UHPC wet joints can achieve good results.

(3) As the strength of the post-poured concrete at the joints increases, the ultimate bearing capacity of the structure, the bearing capacity when the steel bar yields, and the bearing capacity when cracking are all increased accordingly. Among them, the change of cracking load is the most obvious. The increase in yield strength and ultimate load of steel bars is not very obvious. To a certain extent, it shows that the increase in the strength of the concrete in the post-casting joints has a significant improvement in the performance of the joints in this province, but it has The performance improvement of the structure is not very obvious.

From the research results, UHPC-annular reinforcement wet joint have good mechanical properties, especially the improvement of the concrete strength of the post-cast wet joints, but the performance of the joints in the province is significantly improved, but the performance of the entire structure is improved. not so obvious. Therefore, it is recommended to conduct further research on the influencing factors of wet joints, including the influence of the width of wet joints, the form of steel bars and the reinforcement ratio on the mechanical properties of UHPC-annular reinforcement wet joint.

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