STUDY ON REACTIVE POWDER CONCRETE USED IN THE SIDEWALK SYSTEM OF THE QINGHAI-TIBET RAILWAY BRIDGE

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Abstract

The Qinghai-Tibet railway lies in the west area of China at an altitude of more than 4,000 meters. The 576-km railway is being built on frozen earth. The bad climate and sandstorms of the tundra require the concrete of the bridge to have superior mechanical properties and high durability. By adding portland cement, silica fume, superfine fly ash, and superplasticizers, reactive powder concrete (RPC) is used in the sidewalk systems of bridges with compressive strength of 160 MPa. The research shows that RPC has high strength, excellent frost durability, and impermeability. Therefore, RPC is the best choice for the Qinghai-Tibet railway.

1. Introduction

The Qinghai-Tibet railway lies in Qinghai-Tibet plateau in the west area of China, at an altitude of more than 4,000 meters and in a high intensity earthquake region. The 576-km railway is being built on frozen earth. The climate conditions are harsh in that area: low air temperature, concentrated rain and snow, and heavy sandstorms. The area also has complicated geology conditions, and groundwater causes corrosion. The

conditions mentioned above require the concrete used for the bridges to have superior mechanical properties and high durability.

As the subsidiary facility of the railway bridge, the sidewalk system needs to support the load from the passersby and from some small machines and equipment for maintenance of the bridge. The traditional sidewalk system of the railway bridge is composed of angle steel brackets and a concrete flat. The traditional sidewalk system will be prone to be out of order due to low durability of concrete and angle steel bracket and thus needs a great deal of maintenance to keep it in service. Therefore, it is not suitable for the bridges in the Qinghai-Tibet region. A new type of sidewalk system with low weight and high durability is needed for the Qinghai-Tibet railway. To adapt to severe conditions on the Qinghai-Tibet plateau and to meet the requirements of railway developments, reactive powder concrete (RPC) has been developed by the common production process workflow with national material in this research. RPC has high strength and high durability, including excellent impermeability of chloride and frost-resistance. At the same time, the structure members of sidewalk system for the Qinghai-Tibet railway, including flats, brackets, and rails, have been manufactured.

2. Material and Mechanics Function of the Reactive Powder Concrete

2.1. Material preparation

This research concerns $42.5^{\#}$ portland cement, active mineral powder, including high-quality silica fume whose ratio surface exceeds 200,000 cm^3/g, low-need water superfine fly ash, superplasticizers that have good compatibility with cement, whose rate of reducing water is above 32 percent, and quartz sands whose grain size are 0.16 to 0.315 mm, 0.315 to 0.63 mm, 0.63 to 1.0 mm, and that make up the most close-grained preparation. It is detected that grain size of the two materials is very different, and they form discontinuous preparation in the course of arranging cementitious property and aggregates. Therefore, higher mineral powder whose grain size is between cementitious properties and aggregates has been produced.

2.2. Methods of experiment and equipments

The test of concrete compressive strength, elastic modulus, and bending strength is carried under the guidance of "methods of experiment for mechanics function of common concrete." The size of specimens is 100×100×100 mm, 100×100×300 mm, and 100×100×400 mm. However, the velocity of increasing load of compressive strength has been changed to 10 kn/s.

The equipment used for this experiment includes a SJD-30 compelling concrete agitating machine, a high frequency concrete vibrating table, a BYS-3 automatic temperature control instrument, a HJ-84 concrete accelerating cure box, a 3,000-kn electronic hydraulic pressure machine, a 1,000-kn electronic hydraulic universal testing machine, an agitating sand testing machine, an and elastic modulus testing machine.

2.3. Mechanics function of the reactive powder concrete

In order to study the influence of the different mixture ratio on the RPC material function, the following has been studied: the influence of w/b ratio, admixture of mineral additive, compounding between different preparation aggregates and cementitious property, admixture of additive, admixture of steel fibers, curing temperature, and curing system. Through hundreds of mixture ratio experimentation, the optimal mixture ratio, whose w/b ratio is 0.16, whose curing temperature is 75°C, and whose mechanics function, is confirmed on the basis of routine agitating and moulding technology. It is known that concrete's 28-day compressive strength is 168.6 MPa, bending strength is 20.6 MPa, and elastic modulus is 46.8 Gpa, as shown in Table 1.

Table 1: Experimentation result of the optimal mixture ratio

	Compressive strength (MPa)		Bending strength (MPa)		Elastic modulus (GPa)	Slump (mm)
	3d	28d	3d	28d		
Result	169.4	168.6	18.4	20.6	46.8	125

3. Durability of Reactive Powder Concrete

In such severe conditions as on the Qinghai-Tibet plateau, the durability, security, and service life of structures will be distinctly reduced due to the reasons such as the initial flaw of the concrete cast in-suite in a low temperature, subjectivity of the concrete to frosting and thawing, and erosion caused by groundwater brine. What is most important for the concrete structures of the Qinghai-Tibet railway is the good frost-resistance and impermeability of chloride. In order to test frost durability and impermeability of chloride of RPC, the experiments have been done according to the experiment method for frost durability and impermeability of chloride of conventional concrete, which can be found in the GBJ 82-85.

Chloride impermeability is the ability of concrete to resist high-pressed liquid such as water penetrating the concrete. The wearing off of concrete, either physical or chemical, is concerned with water penetration. So, impermeability of chloride almost becomes the core problem of durability of most concrete.

3.1. Chloride impermeability

The experiment was done to investigate the chloride impermeability of RPC on six specimens based on optimal mix proportion. There was no water leakage through RPC in the six specimens when hydraulic pressure varies from 0.1 to 1.6 MPa with increase of 0.1 MPa/8h. When hydraulic pressure was taken away, there was only 2.7-mm penetration in a specimen with initial flaw. As a result, the conclusion can be reached that RPC has excellent chloride impermeability, caber-resistance, and corrosion-resistance.

3.2. Frost resistance

The freeze-thaw test was done to investigate frost-resistance of RPC on two series of specimens. These specimens were dropped in 20^{o}C water for 4 days. The size of the specimens used in the experiment was 100×100×400 mm^{3}. The test temperature for one series of specimens ranged from negative 17^{o}C to negative 13^{o}C, while another

from 4°C to 8°C, and every cycle lasted 4 hours. After 800 cycles of freezing and thawing, relative modulus of elasticity of RPC was still 100%, whereas the lost weight ratio was 0, and the durability ratio was 2.67. From the results, the conclusion can be reached that RPC has excellent frost-resistance. Therefore, RPC is more suitable for the bridges of Qinghai-Tibet Railway than conventional concrete.

4. Study on the RPC Sidewalk System

There are a lot of different problems with conventional concrete sidewalks such as corrosion, rust of reinforcing steel bars, and breakability of concrete slab. The steel brackets rust in a conventional concrete sidewalk. As a result, a conventional concrete sidewalk system requires maintenance every year. Dead weight of the traditional sidewalk system is greater than that of the RPC sidewalk system, which makes bridges have a bad dynamic performance. To improve the conventional sidewalk system, RPC sidewalk system has been developed in Beijing Jiaotong University.

An RPC sidewalk system composed of pre-cast slabs, brackets, and rails is assembled in-suite. RPC, based on optimal mixture ratio, meets the design requirements of sidewalk that the compressive strength should be greater than 120 MPa, and the split tensile strength should be greater than 12 MPa. Based on the optimal mix proportion mentioned above, the production process workflow for structural members used for RPC sidewalk system has been studied in a bridge manufacture. The slump of RPC is greater than 180 mm. With an excellent workability, RPC can meet the requirements of construction. The main mechanical properties of RPC samples are listed in the Table 2. At a reliability of 95%, the compressive strength is greater than 7.0 MPa according to qualification test of RPC. Therefore, mechanical properties of RPC can meet the design requirements of the sidewalk system. One pre-cast bracket of RPC sidewalk system is shown in Fig. 1. The sidewalk system made of RPC has such merits as small deadweight, excellent durability, low cost, and minimum maintenance. Thus, RPC is more suitable for the sidewalk system of Qinghai-Tibet Railway than conventional concrete.

Table 2: Main mechanical properties of RPC

Compressive strength (MPa)		Split tensile strength (MPa)		Elastic modulus (GPa)
6d	28d	6d	28d	28d
157.0	147.3	15.0	21.1	48.5

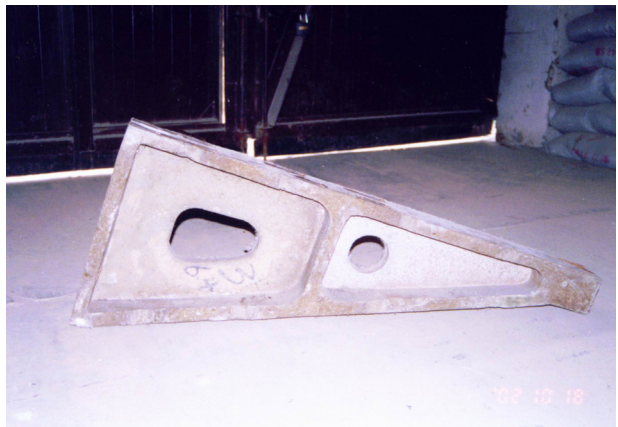

Fig. 1: Pre-cast bracket of RPC sidewalk system

5. Conclusion

The reactive powder concrete produced by routine concrete manufacture techniques has compressive strength above 160 MPa, bending strength above 20 MPa, fine frost resistance, and impermeability of chloride. The sidewalk flat system produced by the reactive powder concrete has light deadweight, low cost, and the littler workload, which makes it suitable for bridge and its subsidiary facilities on the Qinghai-Tibet plateau. Structural members have fine and steady quality and can satisfy the demand of practice production.