Research on the Resistance of Pier C45 Concrete to Chloride Ion Penetration

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Abstract. For composites with 50%, 60% and 70% concrete content of fly ash and grinding blast furnace slag, 17 composite ratios were designed. The effect of composite ratio of mineral admixture on the migration coefficient of chloride ion of C45 bridge pier concrete was studied by test method for rapid chloride ions migration coefficient. The cost analysis of the concrete which meets permeability of resistance to chloride ions was carried out. The results show that: With the increase of the proportion of fly ash and grinding blast furnace slag, the 28d chloride ions migration coefficient of concrete with different admixtures is generally reduced.

1. Introduction
The construction of the cross-sea bridge not only promotes local economic development, but also facilitates transportation. But the construction of the cross-sea bridge requires a large amount of investment from the state, According to statistics, so far China has invested about 251.84 billion yuan to build 66 sea-crossing bridges [1]. The pier, as the only vertical support member in the lower part of the bridge, is directly related to the normal operation of the cross-sea bridge. The investigation found that the damage to the lower structure of the bridge was mainly caused by the corrosion of steel bars caused by chloride ions in seawater [2]. The study by Cao Yanfeng [3] showed that the resistance to Cl-permeation of C35 concrete increased with the increase of the amount of admixture, and the effect of improving fly ash was higher than that of mineral powder. The study in [4] showed that the appropriate composite ratio of fly ash and grinding blast furnace slag can improve the anti-Cl-permeability of C45 concrete of Chongqi Bridge pier body. Chen Qian [5] and other studies showed that: when the composite content of fly ash and grinding blast furnace slag is 50% and the composite ratio is 1: 1, the anti-Cl-permeability of Tianjin Metro C40 concrete is the best. References [3] and [5] have the highest admixtures of 38% and 50%, respectively. Considering the high chloride resistance of concrete required in seawater, large admixtures are generally used. The literature [3]-[5] designed the concrete mix ratio group is at most 7 groups, the research is not systematic and no economic analysis has been carried out. Therefore, this paper designs 17 groups of high-mix admixture concrete with different composite ratios of fly ash and grinding blast furnace slag, and systematically studies the effect of the composite ratio of fly ash and grinding blast furnace slag on the anti-Cl-permeability of C45 pier concrete. And economic analysis is performed, and a low cost and good anti-Cl-permeation performance ratio is preferred.
2. Raw materials, test methods and test design

2.1. Raw materials
P. O 42.5 ordinary Portland cement, Grade II fly ash and grade S95 grinding blast furnace slag, Specific surface area not less than 4000cm$^2$/g, See Table 1 to Table 3 for performance indicators.5 ~ 20mm continuous graded crushed stone, Apparent density is 2700 kg / m$^3$, Fineness modulus is 2.72 graded river sand. Polycarboxylic acid superplasticizer with a solid content of 40%.

| Table 1. Cement Performance Index. |
|-----------------------------------|
| Setting time/ min | Flexural strength/MPa | Compressive strength/MPa | Stability |
| Initial setting | Final coagulation | 3d | 28d | 3d | 28d | (Cake method) |
| 180 | 278 | 6.1 | 9.4 | 28.0 | 55.0 | qualified |

| Table 2. Fly ash technical indicators. |
|--------------------------------------|
| Fineness/% | Water demand/% | Water content/% | Loss on ignition/% |
| 22.5 | 102 | 0.6 | 7.0 |

| Table 3. Technical Specifications of Mineral Powder. |
|--------------------------------------------------|
| Mobility ratio/% | Water content/% | Loss on ignition/% | Activity index/% |
| 98 | 0.4 | 1.24 | 3d | 79 | 28d | 100 |

2.2. Experiment method
According to the Standard for Test Methods of Long-term Performance and Durability of Ordinary Concrete [6] (GB/T50082-2009), RCM method for testing chloride ion mobility coefficient of concrete at 28d.

2.3. Test design
This study is based on a southern sea-crossing bridge project, with actual engineering requirements. The concrete bridge pier is made of C45 high-performance concrete, and the 28d chloride ion mobility coefficient DRCM is less than 1.5 × 10$^{-12}$m$^2$/s. Grade II fly ash and S95 grinding blast furnace slag are blended. Three blending amounts of 50%, 60% and 70% are selected. For each blending amount, 5 to 6 fly ash and grinding blast furnace slag blending ratios are set. When the compounded amount and ratio of fly ash and grinding blast furnace slag are different, the water-binder ratio is adjusted to maintain the same strength level of the concrete. Adjust the polycarboxylic acid superplasticizer content and sand rate to make the concrete mix workability meet the requirements of large fluidity. Concrete sand rate is 40%, Unit water consumption is 160kg. Concrete mix ratio and main performance indicators are shown in Table 4.
Table 4. Concrete mix ratio, slump and compressive strength of standard curing 28d cub.

| Serial number | Water to glue ratio | Mix ratio C: F: SL: S: G: WR (%) | Slump /mm | 28d cube compressive strength/MPa |
|---------------|---------------------|----------------------------------|-----------|----------------------------------|
| 50S           | 0.42                | 0.50:0.00:0.50:1.98:2.97:0.32     | 190       | 52.8                             |
| 10F40S        | 0.43                | 0.50:0.10:0.40:1.98:2.97:0.35     | 170       | 54.4                             |
| 20F30S        | 0.42                | 0.50:0.20:0.30:1.96:2.94:0.40     | 180       | 56.5                             |
| 30F20S        | 0.37                | 0.50:0.30:0.20:1.68:2.51:0.46     | 190       | 57.9                             |
| 40F10S        | 0.32                | 0.50:0.40:0.10:1.39:2.08:0.48     | 215       | 62.8                             |
| 50F           | 0.28                | 0.50:0.50:0.00:1.15:1.73:1.50     | 210       | 58.5                             |
| 60S           | 0.37                | 0.40:0.00:0.60:1.70:2.56:0.31     | 200       | 54.7                             |
| 10F50S        | 0.40                | 0.40:0.10:0.50:1.85:2.77:0.36     | 210       | 56.0                             |
| 20F40S        | 0.38                | 0.40:0.20:0.40:1.72:2.59:0.43     | 200       | 54.5                             |
| 30F30S        | 0.37                | 0.40:0.30:0.30:1.67:2.51:0.44     | 185       | 58.4                             |
| 40F20S        | 0.32                | 0.40:0.40:0.20:1.39:2.08:0.46     | 213       | 58.9                             |
| 50F10S        | 0.28                | 0.40:0.50:0.10:1.15:1.72:1.48     | 210       | 57.8                             |
| 10F60S        | 0.36                | 0.30:0.10:0.60:1.59:2.38:0.37     | 170       | 57.4                             |
| 20F50S        | 0.36                | 0.30:0.20:0.50:1.60:2.41:0.42     | 185       | 57.9                             |
| 30F40S        | 0.34                | 0.30:0.30:0.40:1.46:2.19:0.49     | 180       | 57.4                             |
| 40F30S        | 0.32                | 0.30:0.40:0.30:1.38:2.07:0.44     | 205       | 57.6                             |
| 50F20S        | 0.28                | 0.30:0.50:0.20:1.14:1.72:1.46     | 210       | 56.0                             |

Note: ①50S—Represents concrete mixed with 50% mineral powder; 10F40S—represents concrete mixed with 10% fly ash and 40% grinding blast furnace slag; ②C, F, SL, S, G, WR—Represents the proportion of cement, grade II fly ash, S95 grinding blast furnace slag, river sand, crushed stone, and water reducing agent in the mixing ratio.

It can be seen from Table 4 that the slump of the 17 concrete serial numbers is in the range of 170mm-210mm, and the cohesiveness and water retention are qualified, all of which can meet the requirements of high fluidity concrete and workability. Except for the 50d concrete Standard maintenance 28d compressive strength which cannot meet the C45 strength grade requirements, the other serial number concrete meets the requirements, and the 40F10S concrete compressive strength reaches the C50 strength grade requirement.

3. Results and test analysis

When the combined amounts of fly ash and slag are 50%, 60% and 70%, respectively, the effect of the composite ratio of fly ash and grinding blast furnace slag on the chloride ion migration coefficient of Cd concrete 28d is shown in Figures 1-3.
Figure 1. Effect of fly ash-slag powder composite ratio on chloride ion migration coefficient when the admixture content is 50%.

Figure 2. Effect of fly ash-slag powder composite ratio on chloride ion migration coefficient when the admixture content is 60%.

Figure 3. Effect of fly ash-slag powder composite ratio on chloride ion migration coefficient when the admixture content is 70%.

From Figures 1 to 3, it can be seen that when the admixtures are 50%, 60%, and 70%, as the composite ratio of fly ash and grinding blast furnace slag fine powder increases, the 28d chloride ion migration coefficient of concrete is generally decreased, there is a significant difference in the reduction range in different intervals of the composite ratio of fly ash and grinding blast furnace slag fine powder.

When the admixture content is 50%, the composite ratio of fly ash and grinding blast furnace slag fine powder is in the range of 0: 50-30: 20, 30: 20-40: 10 and 40: 10-50: 0, respectively. The law of change of ion mobility coefficient is obvious decrease, obvious decrease and slightly increase. The 28d chloride ion migration coefficient of concrete with a composite ratio of fly ash and grinding blast furnace slag fine powder of 0:50 is the highest at $3.62 \times 10^{-12} \text{m}^2/\text{s}$, and the 28d chloride ion migration coefficient of concrete with a composite ratio of fly ash and grinding blast furnace slag fine powder of 50:0 is the second lowest It is $1.296 \times 10^{-12} \text{m}^2/\text{s}$. Therefore, when the content of the admixture is 50%, the 28d chloride ion mobility coefficient of the concrete decreases as the composite ratio of fly ash and grinding blast furnace slag fine powder increases.

When the content of admixture is 60%, when the composite ratio of fly ash and grinding blast furnace slag fine powder is in the range of 0: 60 - 10: 50 and 10: 50 - 50: 10, the chloride ion migration...
coefficients of 28d of concrete appear respectively. The change is more obvious and the obvious change rule.

When the admixture content is 70%, when the composite ratio of fly ash and grinding blast furnace slag fine powder is in the range of 10: 60 - 20: 50 and 20: 50- 50: 20, the chloride ion migration coefficients of 28d of concrete appear obviously. The change law of the decrease and the more obvious decrease. When the composite ratio of fly ash and grinding blast furnace slag fine powder is 50:20, the 28d chloride ion migration coefficient of the serial number 50F20S concrete is at least $0.573 \times 10^{-12} \text{m}^2 / \text{s}$.

When the admixtures are 50%, 60%, and 70%, respectively, when the composite ratio of fly ash and grinding blast furnace slag fine powder is 0: 50-20: 30, 0: 60-30: 30, and 10: 60-20: 50, the water-binder ratio does not change much, and the decrease in the activity effect of the composite admixture increases the chloride ion migration coefficient of the concrete at 28d; while the micro-aggregate effect of the composite admixture causes the chloride ion migration coefficient of the concrete at 28d to decrease, the latter effect is higher than the former. Therefore, the 28d chloride ion mobility coefficient of concrete decreases as the composite ratio of fly ash and grinding blast furnace slag fine powder increases. When the admixtures are 50%, 60%, and 70%, respectively, when the composite ratio of fly ash and grinding blast furnace slag fine powder is 20: 30-50: 0, 30: 30-50: 10, and 20: 50-50: 20, the reduction of the activity effect of the composite admixture increases the chloride ion migration coefficient of the concrete at 28d; while the decrease of the water-binder ratio and the effect of the admixture micro-aggregate results in the decrease of the chloride ion migration coefficient of the concrete at 28 d, the latter has a high effect to the former. Therefore, the chloride ion migration coefficient of concrete 28d decreases as the composite ratio of fly ash and grinding blast furnace slag fine powder increases. When the composite ratio of fly ash and slag fine powder is increased from 40:10 to 50: 0, the chloride ion migration coefficient of concrete at 28d slightly increases, which needs to be tested repeatedly.

4. Conclusion
With the increase of the composite ratio of fly ash and grinding blast furnace slag, the chloride ion migration coefficient of concrete with different admixtures at 28d is generally decreasing.

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