Actual Measurement and Analysis on the Carbonization Depth of the High Titanium Slag Concrete

Lin-Ze LI[1,2,a,*], Wei CHEN[2,b], Qi-Bin YAO[2,c]

[1]School of Architectural and Civil Engineering, Xihua University, Chengdu, Sichuan, China

[2]School of Architectural and Civil Engineering, Panzhihua University, Panzhihua, Sichuan, China

[a]514806690@qq.com, [b]cw315000@163.com, [c]729009501@qq.com

*Corresponding author

Keywords: Carbonization of Concrete, Arbonization Depth, High Titanium Slag.

Abstract. With the help of the Phenolphthalein reagent method, the concrete carbonization depth of several actual engineering projects has been tested in this paper. The study focuses on the impacts of carbonization time imposed on the concrete carbonization depth. Based on the actual testing data, the conclusion that the carbonization time and carbonization depth of concrete is in power function relation to each other has been reached, providing a basis for the study on the durability of high titanium slag concrete.

Introduction

High titania bearing blast furnace slag (hereinafter referred to the high titanium slag) is a compact slag naturally cooled or sprinklely cooled from the blast furnace slag generated during the vanadium titanium magnetite smelting process of Pangang Group, The high titanium slag includes about 22% TiO2 and 7.94% CaO and MgO [1]. High titanium slag concrete refers to the concrete compounded, partly or for whole, with high titanium slag macadam or high titanium slag sand. As aggregate to manufacture concrete used in engineering works, high titanium slag has appeared in the 1970s. However, the carbonization of the high titanium slag concrete has not yet been reported. Through field tests on the actual engineering projects, the carbonization depth of high titanium slag concrete as well as the concrete strength has been measured in this paper. Besides, the influencing factors and impact of the carbonization depth of high titanium slag concrete have been studied via actual measurement data.

Carbonization Mechanism

The essence of concrete carbonization is the carbonization process of concrete hydration products (e.g. $Ca(OH)_2$ and C-S-H gel, ect.), with the reaction formula shown as follows:

$$CO_2+H_2O=H_2CO_3 \quad (1)$$

$$Ca(OH)_2+H_2CO_3=CaCO_3+2H_2O \quad (2)$$

$$3CaO\ 2SiO_2\ 3H_2O+3H_2CO_3=3CaCO_3+2SiO_2+6H_2O \quad (3)$$

$$2CaO\ SiO2\ 4H2CO3+2H2CO3=2CaCO3+SiO2+6H2O \quad (4)$$

Like general concrete, the hydration products of concrete will also react with acid gases in the air like CO_2, and then generate neutral $CaCO_3$, strengthening the surface of the concrete. In reinforced concrete structure, steel bar will be placed in the concrete cover. Because of the high alkalinity of concrete, a dense layer of passivation film will be generated on its surface. Thus the reinforcing steel bar will be protected from rusting. Because of pores within the concrete structure, the CO_2 will be continuously mixed with such pores which have not yet completely filled with water and react with $Ca(OH)_2$ in the concrete. Consequently, the alkalinity of the concrete decreased. When the carbonization reaction reaches the surface of the steel bar, the passivation film will be broken, and the steel bar rusted. The volume of the corrosion swells to 7 times of its original size and the huge pressure of the expansion put the concrete surrounding the rust under tensile stress. The tensile strength of concrete is just 5% to 10% of its compressive strength. Therefore, the concrete cracks when the tensile stress of concrete exceeds its ultimate tensile strength. Continuously, the cracks spread and lead to structural durability degradation [2].

Field Test and Data Analysis on High Titanium Slag Concrete Carbonization

Test Items and Data

The items of this project (carbonization depth detection of high titanium slag concrete) include Baoding Bridge (1982), Tongzilin Bridge (1989), and Midi Bridge (1969) in Panzhihua City. The concrete rebound value shall be measured by Schmidt hammer and the strength of the concrete shall be calculated in accordance with *the Technical Specifications of Concrete Compressive Strength Detecting through Rebound Method* (JGJ/T23-92). The concrete carbonization depth value shall be measured with the phenolphthalein reagent method. A hole with a 20 mm diameter shall be produced by using impact drill with the same diameter on the surface of the tested area. Then debris and powder in the hole shall be cleaned. Concentration shall be titrated on the inwall of the hole, and the vertical distance between the surfaces to non-discolouring edge at the bottom for twice shall be measured with a depthometer. And the average shall be taken [3].

See Table 1, Table 2 and Table 3 for the testing data of the testing points.

Tab. 1 Data for Each Point of Panzhihua Midi Bridge

SN	1	2	3	4	5	6	7	8	9	10
Average rebound value Rm	30.2	32.0	39.1	38.6	32.6	32.8	38.8	38.8	25.3	32.6
Carbonization depth dm(mm)	7.5	5.7	4.8	4.6	5.6	5.8	5.4	6.0	6.9	5.6
Equivalent value fcu,i(Mpa)	14.5	18.6	26.2	28.4	17.6	16.4	24.1	23.0	14.1	17.6

Tab. 2 Data for Each Point of Panzhihua Tongzilin Bridge

SN	1	2	3	4	5	6	7	8	9	10
Average rebound value Rm	37.5	33.8	34.5	32.9	34.1	35	36.9	36.4	36.6	33.6
Carbonization depth dm(mm)	5.2	4.6	2.7	6.3	5.4	5.0	5.1	5.8	4.5	3.7
Equivalent value fcu,i(Mpa)	22.1	20.9	20.0	17.6	21.7	21.2	23.4	21.6	24.1	22.8

Tab. 3 Data on Each Site of Panzhihua Baoding Bridge

SN	1	2	3	4	5	6	7	8	9
Average rebound value Rm	42.2	48.8	50.2	45.3	42.6	42.5	45.7	42.1	41.2
Carbonization depth dm(mm)	1.25	0.75	1.13	1.4	1.3	1.4	0.9	1.5	1.6
Equivalent value fcu,i(Mpa)	42.6	37.1	57.1	46.3	43.1	40.5	50.2	39.9	38.4

Influence of Carbonization Time on Concrete Carbonization Depth and Degree

Relationship between Carbonization Depth and the Carbonization Time

The relationship between carbonization depth and carbonization time is $X(t)=k\sqrt{t}$, where t refers to carbonization time, X carbonization depth, and k carbonization coefficient. The results of carbonization depth for different years are shown in Fig. 1. Fig.2 is showing the relationship between the carbonization time and carbonization depth of general concrete.

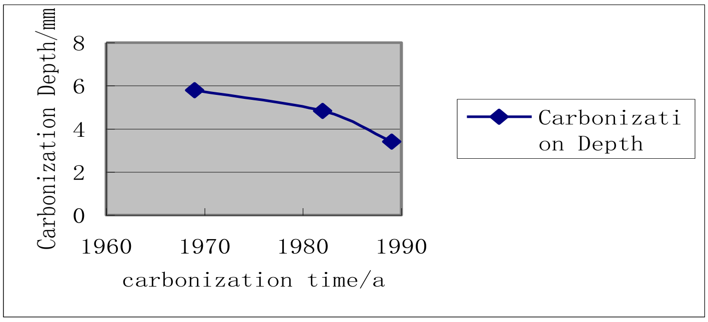

Fig. 1 Influence of Carbonization Time Inserting on Carbonization Depth

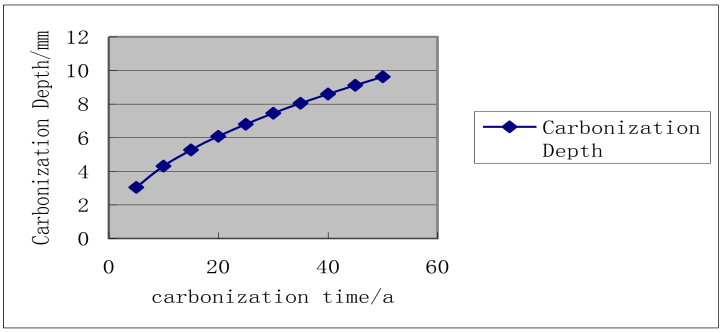

Fig. 2 Relationship between Carbonization Depth and Carbonization Time of General Concrete

It can be seen from Fig.1 and Fig.2 that the relationship between concrete carbonization depth and carbonization time of high titanium slag is roughly the same as that of the general concrete, namely $X(t)=k\sqrt{t}$. The longer carbonization time leads to deeper carbonization. Through quantitative analysis, it can be seen that the carbonization depth of high titanium slag is 0.234 mm within 20 years, and the average carbonization depth of common concrete within 20 years is, on the whole, as the same [4]. But the latter reaches to 6.08 mm 20 years later, while the former is just 5.79 mm .contrast, concrete carbonization of high titanium slag is not as highly as ordinary concrete, 5% less than normal one. Therefore, high titanium slag concrete can replace ordinary concrete and put into use.

Relationship between carbonization depth and concrete strength after carbonizing

Concrete strength after carbonizing is calculated in accordance with the Technical Specifications of Concrete Compressive Strength Detecting through Rebound Method. The relationship between equivalent strength value and carbonization time is shown in Fig. 3.

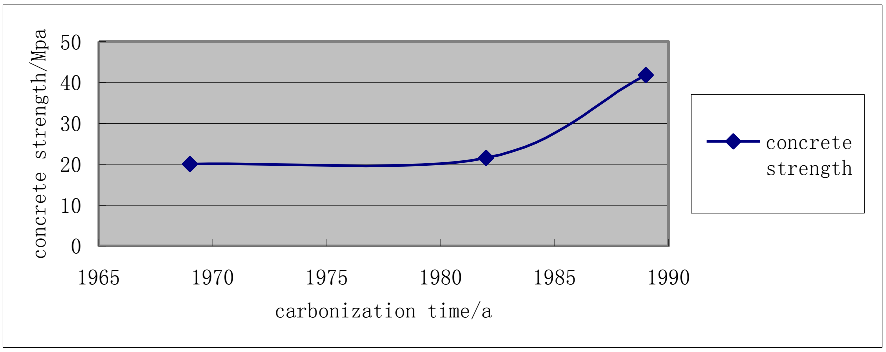

Fig. 3 Influence of Time on Concrete Strength

As shown in Fig.3, we can see that the strength of high titanium slag concrete does not decrease obviously in a short period of time due to the concrete cover. However, as time goes on, the CO_2 in the air will constantly go into the pores which have not yet completely filled with water through the voids within the concrete structure. Consequently, the alkalinity of the concrete will decrease, reinforcement will be rusted and strength of high titanium slag concrete will drop sharply.

Conclusion

1. Through testing and analyzing of the actual projects, we find that high titanium slag concrete carbonization actually presents, and the relationship between carbonization depth and carbonization time of high titanium slag concrete is power function. However, carbonization depth of high titanium slag concrete is 5% less than that of the ordinary concrete within the same period of time. High titanium slag, as aggregate of concrete, enjoys better durability.
2. From the high titanium slag carbonization of concrete strength with the carbonization time, it can be concluded that high titanium slag concrete strength in a short time will not obviously decrease. As the growth of the time, intensity will decrease obviously. Increasing high titanium slag concrete cover thickness can slow the effects of concrete carbonization.
3. Test results show that, the actual project of high titanium slag as concrete aggregate enjoys good durability.

References

[1]Huang Shuanghua, Chen Wei.The application of high titanium slag in concrete material. New building materials [J]. 2006.

[2]Du Yingji, Liang Zhengping. Prediction studies on concrete carbonization depth of Weishui Inverted Siphon project [J]. progress in science and technology of water conservancy and hydropower. 2005.

[3]Evaluation criteria for the durability of concrete structure (CECS220; 2007[M]. China Building Industry Press.

[4]Li Guizhou, Zhou Xingang. Bayesian regression forecasting analysis on concrete carbonization depth[J]. Journal of Yantai University. 2013.