A Study on the Properties of High Performance Concrete with Compound Mineral Admixtures

Jian CHEN*

College of Civil Engineering and Architecture, Wuyi University, Wuyishan, Fujian 354300, China

Abstract — **In this paper, we experiment with steel slag powder, fly ash and silica fume compound admixture to replace part of cement concrete to give better strength and durability. We carry out microscopic analysis of concrete with compound mineral admixtures as the main test content and do compressive strength and resistance to test: i) chloride ion permeability, ii) anti-carbonization, and iii) freeze-thaw cycle performance. We compare the result with the performance benchmark of concrete composite admixture replacement rate in terms of: i) mixing proportion of the material, ii) the relationship between water binder ratio and slag fineness and strength of concrete. These results show: i) the substitution amount of impact with the proposed control 20% ~ 40% range, ii) the water binder ratio being 0.35 for optimal effect. The study on single species admixture in terms of admixture amount and the type of substitution effect of carbonation on high performance concrete, the results show that the anti-carbonation performance of mineral admixture concrete is better than that when the benchmark concrete is low, but the addition of silica fume concrete carbonation resistance is better than that with other admixture of concrete. For chloride ion permeability, test results show three kinds of admixture compound can significantly improve the concrete resistance to chloride ion permeability. The best substitution amount ranges from 40% to 60%. Based on the experimental results, we put forward a calculation model of strength and shrinkage of double mineral admixtures with high performance concrete considering the proportion of fly ash and slag powder and total amount of admixture. The calculated results agree well with the experimental results.**

Keywords - Composite admixture; high performance concrete; carbonation depth; microstructure; property study

I. INTRODUCTION

With the concept of "green concrete" put forward, modern concrete production technology also produces. As one of the development directions of modern concrete, high performance concrete requires the diversification of traditional concrete components. In addition to Portland cement, coarse aggregate and water, high-performance concrete must also include fifth active mineral admixtures and sixth component high efficiency admixture. The activity of mineral admixtures including pulverized slag, steel slag powder, fine fly ash, etc. High efficiency admixture is super plasticizer, retarder, pumping agent, etc. In the early 30s, American scholar R.E.Davis uses fly ash instead of a part of Portland cement, to create a new type of concrete, the fly ash cement concrete mixing, and the first member of the fly ash cement concrete and mineral admixture family material was born. Then the German scholar R.Grunt in 1942 published the "application" of blast furnace slag in the cement industry in a text, which marks the addition of fly ash and a new mineral admixtures slag is used in cement concrete [1]. At the end of 70s, to O.E.Gjorv as the representative of the Norway Institute of technology for the first time in the application of silica fume in concrete made systematic and long-term studies, has achieved significant results, and developed at present the best effect of mineral admixture, silica fume. Our country in the last century in 50s and 60s on the fly ash and slag as admixture of concrete is studied, at the beginning of 70s, China Building Materials Academy first began to use steel slag as cement admixture is studied, from the late 80s to the present, the domestic various research units have developed sulfur slag, grinding limestone powder, fine quartz powder, metakaolin and other new types of mineral admixture. High performance concrete is a new concept developed in 1990s by some developed countries based on durability design of concrete structures. The difference between high performance concrete and traditional concrete is that high performance concrete takes concrete structure durability as the primary technical index. For different requirements, high-performance concrete can be guaranteed durability, workability, strength, applicability, volume stability, economy and other key to ensure. High performance concrete is a new type of high technology concrete, which is made of modern concrete technology. Therefore, with high workability, high volume stability, high impermeability, high durability and high strength and other advantages. High performance concrete has many advantages, such as high bearing capacity, good plasticity and toughness, etc. it has been applied more and more widely in engineering practice. If the high-performance concrete into the steel pipe, the formation of self-compacting high-performance concrete pipe, can give full play to the advantages of two materials. High performance self-compacting concrete is very suitable for application in concrete filled steel tubular structure, it can be in the weight or less vibration condition can be self-compacting molding, convenient construction of concrete filled steel tube, is of great significance to the quality of the project. In the past more than and 10 years, the research and application of high performance concrete achieved significant progress, but the research and application of high performance concrete in China is still in the development stage, there are still many problems of the theory and practice need to actively carry out research, so the research and application of high performance concrete is very necessary. The main characteristics of high performance concrete in the configuration are lower than the water cement mixing enough mineral admixture and high efficient additives. The preparation of high performance concrete, generally only one or two kinds of admixture (additive), and admixture is the main species of slag and fly ash, etc. Because of the obvious difference of fineness and characteristics of all kinds of admixture, so the use of different varieties and different dosage of admixture of high performance concrete, its performance will be significantly different [2]. Composite admixture refers to the concrete adding more than two kinds of mineral admixture and admixture instead of using partial cement in concrete. The main research in this paper is mixed with steel slag powder, fly ash, three kinds of mineral admixture and super plasticizer. Mineral admixtures especially ground mineral admixtures, as concrete admixture can improve or enhance the comprehensive performance of concrete, the mechanism is ground mineral admixtures with micro aggregate effect, nucleation effect, volcano ash effect and morphological effect in concrete. The research topic of this paper based on the performance of high performance concrete is a composite material with high performance concrete, and the most important performance is its durability, the main purpose of this paper is based on knowledge of steel slag powder, fly ash and silica fume itself, through the test in research for more than three composite admixtures preparation of mechanical properties and durability of concrete, and provide a theoretical basis for the engineering application and the production of finished products with compound admixture for high performance concrete materials. The compound research on cement concrete admixture accords with the requirement of modern concrete development, and promotes the development of modern concrete technology. The design trend of modern engineering required for concrete durability as the primary index is to design, to achieve the purpose of high durability, mineral admixture and high efficient additives has become the core technology of high performance concrete. Although the concrete research and application of the material more varieties and quantity, but from decades of our existing construction point of view, the existing mineral admixture in terms of quantity and quality are obviously insufficient, so the development of high performance mineral admixtures can not only meet the demand of modern concrete construction, and will promote the development of the application of modern concrete technology in a certain extent. Concrete micro aggregate effect schematic shown in Figure 1, concrete pozzolanic effect shown in Figure 2. The research and development of cement concrete admixture accord with our country's strategy of sustainable development, pay attention to developing economic and environmental protection, saving resources and energy coordination. As an industrial waste mineral admixture, if it can be widely used in construction, the accumulation of industrial enterprises to industrial waste emissions reduction, reduce pollution of the environment; on the other hand, the concrete production enterprises, using a variety of admixture of concrete, save the amount of cement, thus saving the production of cement the resources and energy. In addition, due to the incorporation of industrial waste, improve the durability of concrete and prolong the service life of concrete, reduce the concrete late maintenance and reconstruction costs, so it has significant economic and social benefits [3].

Figure 1. Schematic diagram of concrete micro aggregate effect

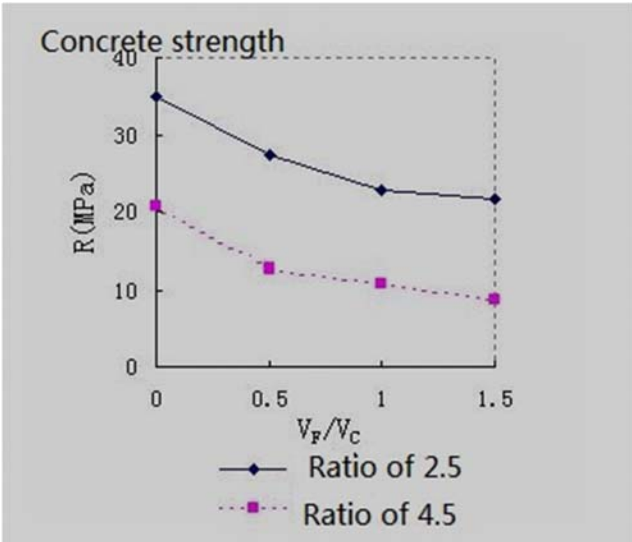

Figure 2. Schematic diagram of effect of pozzolanic effect on concrete strength.

II. RAW MATERIAL PERFORMANCE TEST

A. Raw material selection

The cement used in this experiment is a brand P.II type 42.5 grade Portland cement produced by China cement plant. According to the general Portland cement standard (GB175-2007) and highway engineering cement and cement concrete test code (JTG E30-2005), the main technical properties of cement were tested. Fineness refers to the degree of fineness of cement, it is the cement other technical indicators such as condensation time, strength, water demand and stability have a greater impact, is a major technical indicators to identify the quality of cement. According to the GB175-2007 standard, the specific surface area of the Portland cement sample was 370m2/kg with the air permeability surface area meter, which could meet the requirement of the specification more than 300m2/kg. Cement standard consistency water is in accordance with the provisions of consistency, the quality of 500g cement and water mixing water, measured by the VEKA instrument, by adjusting the water law, to sink into the net bar pulp and white water base 6mm + 1mm from the standard consistency water to cement, mass percent number meter. The standard consistency water content of this test is 28.8%. Coagulation time refers to the time required to start from water to cement slurry lose plasticity. The initial setting time should not be too short, to ensure that there is sufficient time to complete the process of forming concrete operation in the initial setting before; the final setting time not too long, so as to ensure the concrete pouring in forming as soon as possible after hardening to the next process as soon as possible. National current standards: silicate cements initial setting time not earlier than 45min, final coagulation time not later than 6.5h. The initial setting time of this cement is 150min > 45min, final setting time is 250min < 6.5h, meet the standard requirement. The volume stability of cement is the physical performance index of cement after hardening. The factors influencing the volume stability are the content of free calcium oxide (f-CaO) and free Magnesium Oxide (f-MgO) and gypsum content in cement clinker. Because f-CaO and f-MgO are over burned and hydrated slow, they slow hydration and produce volume expansion after the cement is hardened and hardened, resulting in hardened cement cracking. The amount of gypsum in cement is too high; the excess gypsum will react with the solidified calcium aluminate hydrate to produce hydrated calcium sulphoaluminate, resulting in volume expansion, resulting in hardened cement stone cracking [4]. National standard: the volume stability of cement caused by free calcium oxide by Rayleigh clamp method was used to detect the specimen swelling value should be less than 5mm. The test results show that the swelling value of the specimen is 1.85mm - 5mm, which meets the requirements of the specification and the stability is qualified. Cement strength is the main technical index of selecting cement, and is also a main technical index to identify cement quality. This experiment according to the national standard stipulation uses "the cement mortar strength inspection standard (ISO method) to measure the cement intensity. This method is the cement and sand standard according to the mass ratio of 1:3, water cement ratio of 0.5, according to the provisions of 40mm * 40mm * 160mm method made the specimen 3, with mould in standard curing room curing 24h after demolding on standard temperature (20℃ ± 1℃) maintenance flowing water, were determined by age during the period of the flexural strength and compressive strength of cement mortar 3d, 28d.

B. *Orthogonal Experimental Design*

This experiment mainly investigated with steel slag powder (hereinafter referred to as GZ), fly ash (hereinafter referred to as FM) and silica fume (hereinafter referred to as GH) three kinds of admixtures to replace the total substitution amount was 20%, cement 40%, 60%; three kinds of mineral admixture ratio between GZ:FM:GH to 3:5:2, 4:5:1, 3:6:1. The water cement ratio is 0.35, 0.38, 0.41; the fineness of steel slag above D1 (surface area of 380m2/kg (D2), specific surface area is 396m2/kg (D3), 405m2/kg surface area) three fineness level. Water reducing agent is 1.5% of the total amount of cement like material. Orthogonal design arrangement experiment, select the four factors, according to L9 (35) orthogonal table, Figure 3 for mixed composite admixture concrete orthogonal test factor diagram. Figure 4 Schematic diagram of orthogonal design for composite admixture concrete. The compressive strength of concrete refers to the maximum pressure that can be sustained on the unit area before fracturing, and it is the main mechanical index of concrete. The corresponding standards of all countries are the compressive strength obtained from the test under certain conditions under certain conditions. When the compressive strength is measured, the result is related to the shape and size of the specimen. At present, the international to determine the shape of specimens with the compressive strength of concrete cubes and cylinders two, China's major compressive strength value as the basic standard of concrete strength, and the United States, Japan and other countries with the cylinder compressive strength as the standard. These two kinds of specimens have their own advantages, the cube specimen is more regular and the strength is relatively stable. The compressive strength of the cylinder specimen is closer to the actual stress characteristics of the concrete members. Using 100mm * 100mm * 100mm cube specimen, using artificial stirring molding. When the first mixing various cementitious materials and fine aggregate dry mix, then thickened aggregate dry mix, then add dissolved super plasticizer water, stirring after discharging and immediately test the initial slump. Before making, the mold should be cleaned, and the test mold surface coated with a thin layer of mineral oil, in order to facilitate stripping. The fresh concrete after mixing is divided into two layers into the trial mould, and the thickness of each layer is approximately equal. When in the spiral direction from the edge to the center evenly. Vibrating bottom rod should reach the bottom mold, vibrating rod should be penetrated into the upper, lower depth is about 20 ~ 30mm. When the vibrating rod shall keep vertical tilt, and with a spatula along the mold wall into several times, in order to prevent the specimen from loose and pits. Then with a scraper along the mold edge will scrape the mixture excess, and knife to smooth surface. In the standard curing room (20 ±3℃, relative humidity is greater than or equal to 90%) 48 hours of maintenance, and removal of no.. After the removal of the specimen to put in standard curing room curing for specified period to determine the compressive strength. Concrete compressive strength test, the specimen from the maintenance chamber removed, placed on the lower pressure plate, the specimen bearing surface should be perpendicular to the top surface. The center of the specimen shall be aligned with the center of the lower press plate of the testing machine. Start the test machine, when in contact with the test plate, adjust the tee, and make contact balance. The average value of the measured values of 3 specimens was used as the compressive strength value of the specimens. When the difference between the maximum value and the minimum value of the 3 measured values exceeds the value of the intermediate value more than 15% of the intermediate value, the maximum value and the minimum value are separately removed, and the intermediate value is taken as the compressive strength value of the specimen. If the maximum and minimum values differ from the intermediate values by more than 15%, the test results of the group are invalid. The compressive strength of concrete is 150mm * 150mm * 150mm cubic compressive strength as the standard, with the other specimen measured intensity values should be multiplied by the size conversion coefficient of the specimens used in this experiment, 100mm * 100mm * 100mm, the conversion coefficient of 0.95[5].

Factor level	A	B	C	D
	Amount of substitution (%)	GZ:FM:GH	Water binder ratio	The specific surface area of the steel slag (m^2/kg)
1	20	3:5:2	0.35	380
2	40	4:5:1	0.38	396
3	60	3:6:1	0.41	405

Figure 3. Schematic diagram of factors and levels of orthogonal test

Experiment serial number	C	W	GZ	FM	GH	S	G	A
S1	352	154.0	26.4	44.0	17.6	762.4	1143.6	6.6
S2	352	167.2	35.2	44.0	8.8	757.1	1135.7	6.6
S3	352	180.4	26.4	52.8	8.8	751.8	1127.8	6.6
S4	264	167.2	52.8	88.0	35.2	757.1	1135.7	6.6
S5	264	180.4	70.4	88.0	17.6	751.8	1127.8	6.6
S6	264	154.0	52.8	105.6	17.6	762.4	1143.6	6.6
S7	176	180.4	79.2	132.0	52.8	751.8	1127.8	6.6
S8	176	154.0	105.6	132.0	26.4	762.4	1143.6	6.6
S9	176	167.2	79.2	158.4	26.4	757.1	1135.7	6.6
S0	440	167.2	0	0	0	757.1	1135.7	6.6

Figure 4. Schematic diagram of orthogonal design

C. *Compressive Strength of Composite Admixture Concrete*

Concrete compressive strength test, the specimen from the maintenance chamber removed, placed on the lower pressure plate, the specimen bearing surface should be perpendicular to the top surface. The center of the specimen shall be aligned with the center of the lower press plate of the testing machine. Start the test machine, when in contact with the test plate, adjust the tee, and make contact balance. The pressure should be continuous and uniform loading, when the concrete strength is not less than C30, the load speed is 0.5 ~ 0.8MPa/s. when the specimen is close to failure and quickly began to deformation, stop adjustment test for throttle, until the specimen, record the failure load of P. According to the concrete compressive strength test method and orthogonal test ratio, forming concrete test pieces, measuring the compressive strength of composite admixture concrete for 7 days, 28 days, 90 days as the evaluation index. Range analysis mainly uses the magnitude of the range R to determine the primary and secondary order of each influencing factor and the range of the I column factor: Ri = max (I I, II I, III I) -min (I I, II I, III I). The magnitude of the range R reflects the magnitude of the corresponding factors. Factor range large, means that the effects of different levels of the factors caused by the index is larger, usually is the main factor; factor range small, means that the smaller effects of different levels of the factors caused by the index, is usually a minor factor. In each age of concrete, the influence of 4 selected factors on the compressive strength of the composite admixture concrete is as follows: A>C>B>D. That is to say, the amount of substitution has the greatest influence on the compressive strength of concrete with mixed admixtures, the influence of water binder ratio is the second, and the influence of steel slag fineness is the least. Take each factor three level as the horizontal coordinate, by each level correspondence K1, the K2, the K3 value as the ordinate, draws the same factor different level to the compression strength influence graph as shown in Figure 5, 6, 7. According to the results of range analysis, we can get the following conclusions: substitution is the most important factor affecting the strength of composite admixture concrete. In the early days, with the substitution quantity increases, the compressive strength of concrete decreased gradually, especially when the substitution amount reaches 60%, 7 days of pure cement concrete strength is only about 30% or so, the 28 day strength has barely reached 50%, because the cement proportion is relatively reduced, and the early strength of cement is mainly produced by water the reaction of the mineral admixtures activity in the alkaline environment need certain to be able to stimulate. Water to binder ratio is the second significant factor influencing the strength of composite concrete after the substitution amount. The strength of concrete decreased linearly with the increase of water binder ratio. This paper selected the water cement ratio were 0.35, 0.38, 0.41, and adding super plasticizer in water gel under the conditions of low, increasing the fluidity of fresh concrete, the concrete structure to increase the degree of compaction[6]. Therefore, the lower the water cement ratio, the higher the strength of concrete. The proportion of the three admixtures also has some influence on the strength of concrete. In certain dosage range, such as GZ:FM:GH is 3:5:2, equivalent to increase the amount of silica fume, can effectively improve the early strength of concrete. Because of the unique properties of silica fume is its fineness, high degree of amorphous and high SiO_2 content. Between the spherical fines particles filled with cement particles, with steel slag powder, fly ash, in three different magnitude of the average particle size, the cementitious material has good gradation, and water mixing after filling in cement paste pore, from the micro scale increases the compactness of concrete. Reinforced cement matrix. However, due to the combination of silica fume and fly ash, the three promote each other, can effectively enhance the strength growth in the mid and late stages. When the ratio of GZ:FM:GH to 3:6:1, the amount of fly ash is three kinds of admixture in the most, but poor activity of fly ash, volcano ash slow reaction rate and strength development is slow, high content of fly ash on the development of early strength and disadvantage, the greater the fly ash, the early strength is low. Sometimes not only cannot play an enhanced role, and even have a negative impact on the composite system. 7 days and 28 days fly ash hydration degree is limited, the contribution rate of strength is also small.

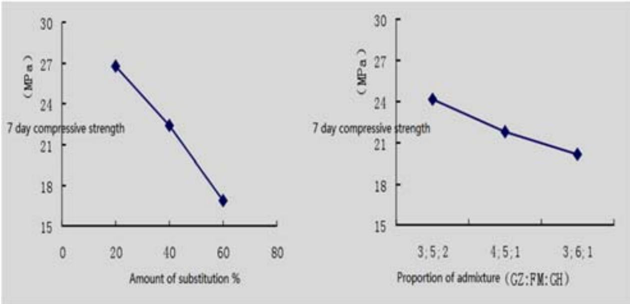

Figure 5. Effect of substitution amount and blending ratio on compressive strength of 7 days

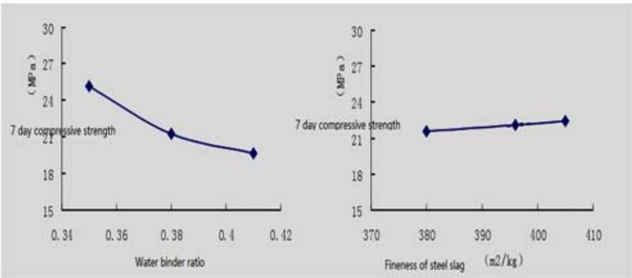

Figure 6. Influence of water binder ratio and steel slag fineness on compressive strength of 7 days

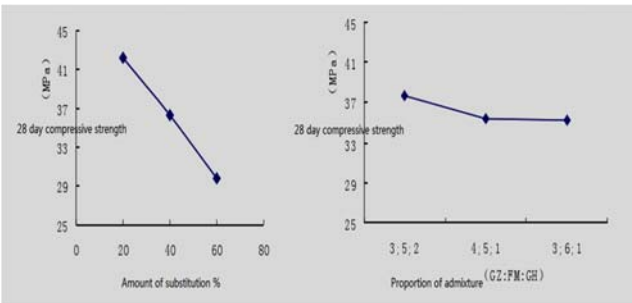

Figure 7. Effect of substitution amount and blending ratio on compressive strength of 28 days

III. STUDY ON DURABILITY OF COMPOSITE ADMIXTURE CONCRETE

A. *Experimental Study on Chloride Ion Permeability of Composite Concrete*

The permeability of modern concrete is not only meaningful to the structure with waterproof requirements, but also to evaluate the resistance of concrete to erosion and corrosion. Corrosion of steel bar is one of the main problems of structural failure and durability of concrete structures. Although the environmental factors causing corrosion of steel bar have many aspects, the effect of chloride ion is considered one of the main factors. Professor Mehta (P.K.Mehta) summed up the world's 50 years of durability of concrete, steel corrosion is recognized as the first factor affecting durability. China's existing environmental chloride widely, a long coastline, the vast northern region in the marine environment; the snow still uses the chlorine salt "snow melting agent", which have led to the erosion of chloride ions is the most important factor influencing the durability of concrete. Damage of chloride ion on the steel surface passivation occurs in the first part (point), these areas (spots) with iron matrix, and passivation region still intact constitutes a potential difference between the iron substrate as anode and corrosion, passivation film as the cathode area. This is the chloride ion on the rebar surface to "pit erosion" the main reason for the destruction. There are a variety of the diffusion model of chloride ions in concrete, usually under the diffusion of chloride penetration in concrete behavior can be Fick's second law of diffusion to describe, and get a certain initial and boundary conditions of the mathematical solution. The migration of chloride ions in concrete is a very complex process, complex diffusion, capillary suction and penetration movement form, in addition to their own concrete performance influence, is also affected by various environmental factors, so it is a non-stable process. Many factors can affect the diffusion of chloride ions in concrete, concrete materials, the environment of the Fick's second law for further improvement based on chloride ion total chloride ion in concrete mix proportion, free humidity structural heat exposure conditions in different conditions of chloride diffusion have different correction coefficient equation. The chloride ion diffusion coefficient through many determination methods, the existing methods are mainly divided into two categories: (1) the natural diffusion method: natural diffusion method is the concrete long time (usually six months or a year) soaked in chlorine salt water, and then through the slice or drilled by means of chemical analysis, can relationship between chloride concentration and diffusion distance, and then calculate the diffusion coefficient of chloride ions by the size of the Fick's second law. The advantage of the method is closer to reality, but takes longer[7]. (2) accelerated diffusion: the most commonly used method is the rapid determination of diffusion coefficient of electro migration, will be between the specimen ends are respectively arranged on the two kinds of solution and applied potential difference, chlorine salt solution in the upstream, the driving electric field of chloride ion in concrete to rapid transfer, after several hours later. The specimen measured chloride specimen in depth, the theoretical formula can calculate the diffusion coefficient of chloride ion, called fast non steady state diffusion coefficient. The specific test steps for detecting chloride ion penetration power of the detection system are as follows: (1) sampling: take out the concrete standard sample of standard curing in the curing chamber, the size is 100 * 100 * 100mm. (2) sample cutting: after cleaning the floating slurry or contaminants, cut the thickness of 100mm * 100mm * 50mm along the top of the specimen parallel to the top of the specimen. Grind the ends of both ends of the specimen with a grinding wheel. (3) full vacuum salt: stainless steel barrel set the cutting concrete specimens neatly in vertical vacuum chamber, with a gap to sample, if the sample is stratified stacked, between the upper and lower should maintain ventilation; to adjust the height of liquid level sensor, which is vertically placed on the upper surface of the sample, from the top sample 1-2cm position is appropriate; special rubber hose the semicircle channel vacuum chamber at the lower end of the water injection pipe is arranged in the sleeve barrel of the inner wall to prevent water around the cover: sputtering vacuum chamber lid, symmetrical tightening bolts on the cover of the vacuum chamber is closed; and turn off the water valve, open the vacuum pump valve order automatic controller, vacuum chamber, the vacuum pump starts to work, the negative pressure of the vacuum chamber in a steady, upper limit and lower limit of -0.08MPa - 0.06MPa 4-6h; the closed pump valve, injector The water into a 4mol/L NaCl container, open the water valve, the solution was injected into the right position, liquid level automatic controller on the indicator lights to turn off the water valve, and then open the exhaust valve; the vacuum pump starts to work again, the negative pressure vacuum chamber continued stability between the upper and lower limit of -0.06MPa -0.08MPa keep it shut down 1-2h; pump valve and vacuum automatic controller, power off, sealed vacuum chamber, the static 18h; to open suction bleed valve, open the cover of the specimen is removed, prepare permeability test[8]. (4) the EJU fixture and checking fixture for leaks with tap water permeability test sample installation, check no leakage after pouring in tap water, the negative (black terminal) into NaCl 3% solution of the fixture, the positive (red terminal) into NaOH 0.3mol/L solution using test fixture; positive and negative line connection C1202 Permeability Tester host and sample clamp pole; the power supply connected to the mainframe, open the "NELElec" software testing; the total electricity consumption forecast software 6h note, if more than 6000 of Kulun should immediately stop the manual channel, or when the electric capacity of more than 8000 Kulun instruments may be burned; the 6h test time end system power the data will be automatically measured saved. The relationship between concrete electric flux and age mixing admixture diagram as shown in Figure 8.

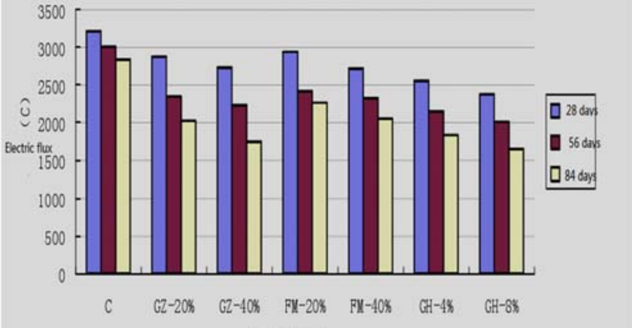

Figure 8. The relationship between concrete electric flux and age mixing admixture

B. *Experimental Study on Carbonation Resistance of Composite Admixtures Concrete*

The carbonation of concrete is also called neutral, refers to the environment of CO2 and calcium hydroxide in water and concrete cement in reaction to produce calcium carbonate and water, thus reducing the alkalinity of concrete phenomenon. Under normal circumstances, early concrete has a very high alkalinity, its pH is generally greater than 12, so that the surface of the steel layer to form a passivation film, can prevent concrete rebar corrosion. The most direct result of concrete carbonation is to reduce the internal pH value of concrete, resulting in steel loss due to alkaline protection and corrosion, carbonation shrinkage will cause micro cracks, so that the strength of concrete decreased. During the initial stage of carbonization also have beneficial effects on the performance of concrete carbonation, the calcium carbonate surface concrete, filling cement stone pore, improve the density, to prevent buffer invasion of harmful media. But to make calcium carbonate into calcium carbide, slightly soluble compound, after the dissolution of the increase of porosity, reduce the concrete resistance to other chemical erosion. The most direct effect of concrete carbonation is to reduce the alkalinity of concrete, Taylor pointed out that the carbonation of concrete PH below 8.5, lower than the steel surface passive film stability exists PH=11.5. So when the concrete carbonation reaches the steel surface, in water and air and other corrosive conditions, the passivation film of the surface of the steel bar will be destroyed, resulting in volume expansion concrete cracks, corrosion material from the crack further invasion, which accelerated the failure of concrete. The negative influence of the concrete carbonation will cause irreversible shrinkage of concrete carbonation, research shows that shrinkage value is closely related with the environmental humidity; generally at 50% relative humidity in the environment, the maximum carbonation shrinkage. This irreversible shrinkage increases the probability of cracking due to shrinkage. Because of the concentration of C02 in air is low, the actual rate of carbonation is slow, carbonation shrinkage caused by the possibility of shrinkage cracking of concrete is small, usually only one year later, make the concrete surface cracks is very subtle. The rate of carbonation of concrete depends on the diffusion rate of CO2 and the reactivity with the concrete composition. The diffusion rate of CO2 is mainly affected by the density of concrete, the concentration of CO2 in the environment and the temperature and humidity of the environment. These factors can be classified into two aspects: internal factors and external factors. The internal factors include cement dosage, cement variety, water cement ratio (W/C), aggregate variety and gradation; external factors have influence on construction quality and maintenance method, outside temperature and humidity and CO2 concentration. At present, there are two indexes to evaluate the carbonation resistance of concrete: carbonation depth and carbonation resistance coefficient. Carbonation depth refers to the thickness of concrete after being subjected to certain carbonation, and the carbonation resistance coefficient is the ratio of the strength of concrete after carbonation and the strength before carbonation. In this paper, carbonation depth as its evaluation index[9]. This test concrete specimen size is 100mm * 100mm * 100mm. Specimens should be generally standard curing to 28 days carbonation, the use of admixtures of concrete can be determined according to its characteristics before curing period. Should be removed from the curing chamber 2 days before carbonization; then bake in the oven at 60 DEG C for 48 hours. The specimen after drying process, in addition to leave two opposite sides, the rest of the surface with heated stone Layu to seal. Draw a parallel line with a pencil at a distance of 10 mm in the longitudinal direction of the side to determine the measurement point of carbonation depth. Single doped, double admixtures concrete carbonation curve schematic shown in Figure 9.

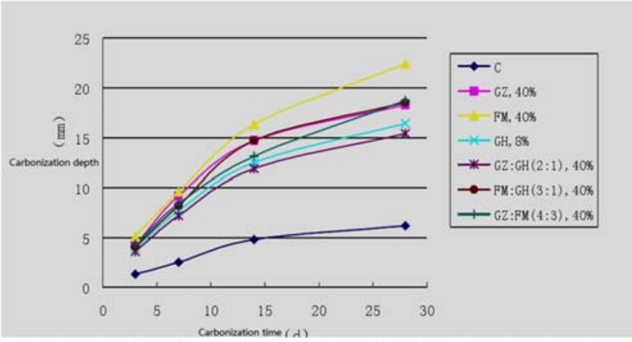

Figure 9. Carbonation curves of single and double admixtures concrete

C. *Performance Test of Composite Admixture Concrete in Freeze-Thaw Cycle*

Concrete in the water state under repeated freezing and thawing will cause internal damage, cracking, aggregate exposed. The main environmental factors related to freeze-thaw damage are water, minimum temperature, cooling rate and repeated freeze-thaw cycles. The freeze-thaw damage of concrete only occurs when the water content is sufficient, which is related to the accumulation of crystallization pressure when the concrete capillary pore water freezes. The T.C.Powers began to study on frost resistance of concrete in freezing mechanism from 1940s, put forward the theory of water pressure and osmotic pressure theory, to establish a complete theoretical system, for many years by the widespread attention in the international academic circles, and laid the foundation for the study of air entraining concrete. The existing frost resistance theory mainly has the following kinds: (1) water pressure theory: the existence of pore water is the key to freeze thawing damage of concrete. According to the nature of the water pressure, it is the role of the instantaneous, usually at the beginning of the ice to reach the maximum value immediately; if the material will not crack, the water will gradually flow out, the pressure gradually disappear to zero. The theory of water pressure can account for many of the manifestations of frost damage in concrete, but Powers and Helmuth et al. Later found some facts in the experiment with the water pressure theory. From the nature of water pressure to understand its role should be instantaneous, with the progress of time hazards should gradually disappear. But the test shows that: concrete freeze damage sometimes with time increasingly fierce, serious; cement slurry frozen, moisture movement is not far away from frozen place, but is precisely to freezing point. These are difficult to explain by the water pressure theory, so Powers put forward another theory of osmotic pressure. (2) Osmotic pressure theory: Gel water to penetrate into the frozen capillary hole, is the key to freeze thawing damage. Cement slurry is usually a dilute solution of salt, when the capillary pore water partially freezes, the solution concentration increases. But in the gel whole water does not freeze, the concentration unchanged, resulting in the concentration difference between the pore solution and gel water, gel to whole water diffusion into the pores. The result is the osmotic pressure, resulting in a certain expansion pressure. (3) The theory of frost heave: frost heaving theory holds that the basic reason of frost damage is not due to the expansion of frozen and simple, mainly from moisture migration (macro scale Xi Bing), the ice crystal growth, and pressure. It is not microscopic capillary ice crystals, but giant ice crystals visible to the naked eye. The huge pressure of ice crystals causes the concrete pavement to swell and destroy. According to the above three theories can be considered: concrete is a porous body composed of cement mortar and coarse aggregate, mixing water added in the mixing process of cement hydration is always more than the required water, this part of the excess water with free water retention of the formation of connected pores in concrete, and share a certain volume, it is the leading cause of internal factors of concrete subjected to freezing. The experimental method to specific size of cube specimens (100mm, 150mm and 200mm in length) at -15 ~ -20 DEG C to 15 ~ 20 C maximum can withstand repeated freeze-thaw cycles as the frost resistance grade of concrete. 100, 150mm cube freezing time piece not less than 4h, the 200mm cube is not less than 6h, the water dissolving time of not less than 4h. For frozen thawed specimens and the same age no injury compared with specimen, decrease the compressive strength value shall not exceed 15%; loss of mass concrete road shall not exceed 5%. Freeze thaw test machine adopts full automatic concrete quick freezing thawing test machine[10]. The freeze-thaw mechanism is frozen concrete specimens of center temperature of -17 to -15 DEG C, melting the specimen center temperature is 6 to 8 DEG C, one freeze-thaw cycle is 4 ~ 6h, the specimen during freezing and melting are in full immersion state (i.e. water saturated state). Specimens should be generally every 50 cycles for a dynamic mode test (DT-16A type dynamic instrument). Before the test specimen from the freeze-thaw cycle out machine, cleaning the surface of the specimen scum, wipes the surface of the water, said the quality of. The relative dynamic modulus and mass loss rate were evaluated to evaluate the frost resistance after rapid freeze-thaw. The relative dynamic modes of the concrete after freeze-thaw cycles are shown in Figure 10. After the freeze-thaw of concrete D0 reaches 300 cycles, there are many fine cracks on the surface, the mass loss is small, and the relative dynamic modulus is about 85.2%. The single doped steel slag powder reached 40% of the specimen D1, in the freeze-thaw cycle after the mass loss of up to 3.36%, after the loss of more than 250 cycles of quality loss of more than 5%. Compared with single doped silica fume 10% D2, in the freeze-thaw cycle after the 300, mass loss of 2%, relative dynamic mode of 71.5%. This indicates that the high amount of substitution and the single admixture will decrease the freeze-thaw cycle performance of concrete. The test results show that three kinds of admixture compound use, is indeed better than the single doped, double doped admixture concrete freeze-thaw resistance stronger, substitution amount during the 20% D5, after 300 cycles of relative dynamic modulus to maintain more than 90%; 60% of the amount of D9 instead of the worst; substitution amount is 40% when D6, D7, D8 three although the admixture proportion is different, but after 300 cycles of relative dynamic modulus and the benchmark D0, suggesting that as long as the admixtures replace quantity and mixed ratio is appropriate, can be through with compound mineral admixtures to replace cement at the same freeze-thaw performance, even increased.

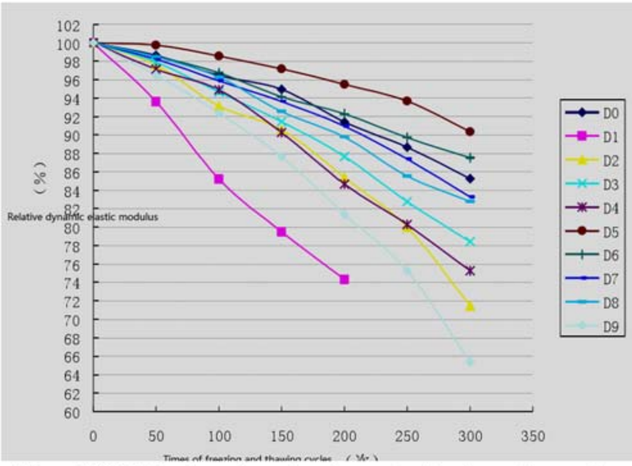

Figure 10. Relative dynamic modes of concrete after freeze-thaw cycles

IV. DRY SHRINKAGE TEST OF COMPOSITE ADMIXTURE CONCRETE

Drying shrinkage is another important performance of concrete materials, which has a very important influence on long-term performance of concrete structures. It is when to stop the concrete curing, irreversible shrinkage loss of adsorbed water internal pores and gel pores in the unsaturated air and produce. This kind of irreversible shrinkage is caused by the change of the micro pore size distribution of the concrete, the change of the bonding between the C-S-H particles and the change of the water distribution in C-S-H, resulting in the permanent rearrangement of C-S-H. From the surface to the internal shrinkage gradually extended dry concrete, surface high shrinkage and internal contraction of small uneven contraction, make the concrete surface cracks, decrease the durability of concrete structures, resulting in the failure of concrete. That capillary tension theory, the definition of macro shrinkage stress, the pressure difference needs to be multiplied by a coefficient of volume per unit area, the volume of cement stone in liquid phase, based on the theory of continuous liquid phase, the pressure difference should be in the liquid phase[11]. According to the T.C.Powers model of micro pore structure and macroscopic shrinkage between the theoretical values close to the measured value, but he found that the prediction result is smaller than the real value test, it was to be attributed to low relative humidity shrinkage mechanism of change. On the microscopic level, water is adsorbed on the surface of C-S-H, and its thickness increases with the increase of humidity. In C-S-H, colloidal particles have attractive van Edward forces that attract nearby particles and give close contact with their adjacent surfaces. The adsorption of water on C-S-H surface was created between the disjoining pressures, open the pressure with the adsorbed water thickness increased about 50% relative humidity, open the pressure over the Fan Dehua force, this will force the particle separation expansion. C-S-H is formed in swelling state during hydration, and micropores are filled with water. The first drying, along with lower relative humidity, reduces the opening pressure, the particles are attracted by the van Edward force, shrinkage. The dry shrinkage test of this paper is based on the "long term performance and durability test method of ordinary concrete" (GBJ 82-85). The prism standard 100mm * 100mm * 515mm specimen, artificial mixing processing, into the standard curing room (temperature 20 ± 2 ℃ , relative humidity is greater than or equal to 95%) maintenance, 3D number, the removal and determination of standard length. Then the specimens were placed in a vertical test device customization, in room temperature and humidity of the natural environment, by the end of the installation on the dial indicator reading different age shrinkage. Experiments used in this experiment, the specific surface area of steel slag 405m2/kg, water cement ratio is 0.38, the proportion of admixture (slag: Fly Ash: SF = 3:5:2), will replace the cement (0.20% ~ 60%) as influence factors, concrete and reference concrete admixture in comparison. Schematic diagram of the relation curve between dry shrinkage strain and age is shown in Figure 11. With the growth of the age, the composite admixture of concrete and reference concrete, dry shrinkage strain gradually increased, the early high growth rate, 70 days after the curve tends to be flat, the slope of the curve gradually tends to zero. In a fixed mixing ratio and water cement ratio, with the substitution amount increases, the change of dry concrete shrinkage strain decreases firstly and then increases, instead of 40%, the lowest dry shrinkage strain, only the reference concrete shrinkage strain is only 69.1%; 61% and 28 days of the reference concrete, namely there is a the best replacement, the minimum dry shrinkage of concrete[12].

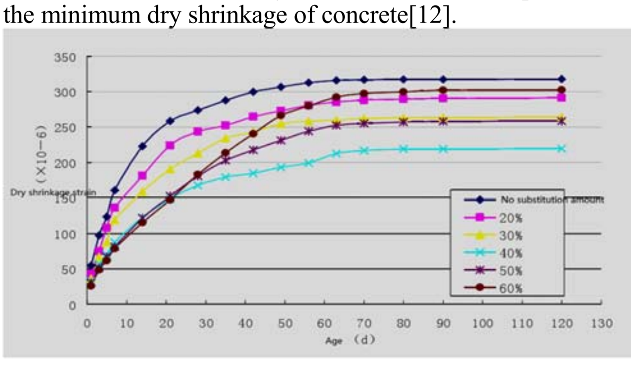

Figure 11. Relationship curves between dry shrinkage strain and age

V. CONCLUSIONS

In this paper, mixed with steel slag powder, fly ash and silica fume to prepare composite admixture, through a large number of laboratory tests, discusses the composite effect of mineral admixture on the strength and durability of concrete, with the increase of age, the compressive strength of concrete with compound mineral admixtures are gradually improved, and the age strength increase rate is higher than the reference concrete, the long-term strength is close to the reference concrete may even exceed the benchmark concrete. Composite admixture replacement rate is the impact of concrete cube compressive strength and splitting tensile strength of the important factors, content is high, the early strength of concrete decrease, while the late strength growth rate also increased accordingly. In order to reduce the early strength of concrete and increase the later strength, the total substitution amount of composite admixture is controlled in the range of 20% ~ 40%. The test results of resistance to chloride ion permeability show that when the substitution amount of composite admixture is above 40%, it is reasonable to evaluate the chloride ion permeability of concrete with 56 days of age as evaluation index. Especially the three admixtures can obviously improve the chloride ion permeability of concrete, the best range of substitution is 40% ~ 60%. The substitution amount is 40% and the steel slag powder, fly ash, the ratio of 4:5:1 to 56 days minimum flux, and the flux of 84 days is the ratio of less than 1000 base substitution amount is 40% and the steel slag powder, fly ash, the ratio of 3:5:2. 54 first decrease and then increase, the replacement amount of 40% is best, dry shrinkage strain is only the benchmark concrete of 69.1%; and the dry shrinkage strain for the first 28 days is only the benchmark concrete of 61%. Below the benchmark concrete early shrinkage of composite admixture of concrete, and the replacement quantity is high, the early shrinkage is smaller; substitution for 7d 60% concrete shrinkage strain is only 48.7% that of base concrete, composite admixture can obviously improve the dry shrinkage of concrete.

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