A Study and Application of the Relation between Concrete Quality and Raw Materials under Multiple Perspectives

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Abstract — **This paper mainly introduces the direct influence of concrete, the most widely-used material in construction engineering, on the structure of construction engineering. Raw materials are an important part of the concrete engineering. This paper analyzes the mixture proportion of cement, mineral additives, fine aggregate and coarse aggregate through the technical index control of raw materials of concrete, mix compaction experiment, strength mix proportion experiment of 2.5~5mm aggregate size, strength mix proportion orthogonal experiment of 5mm aggregate size and mix proportion experiment of 5~10mm aggregate size so as to provide an important technical guarantee for the concrete quality. Advanced raw materials testing equipment can efficiently and correctly test and evaluate the quality of raw materials to meet the construction requirement of the modern concrete engineering and provide important references for further study of the relation between concrete and raw materials.**

Keywords - raw materials; mix proportion study; concrete; fine aggregate; coarse aggregate

I. INTRODUCTION

With the rapid development of science and technology, knowledge economy and urbanization, construction products with concrete as the major materials have become the theme for the development of new techniques, new process and new applications. There is a close relation between concrete end products and raw materials, such as dinas, cement and additive. If the quality and mix proportion relation between the raw materials can be well handled, it efficiently ensures the quality of concrete and its application in construction engineering.

II. OVERVIEW OF CONCRETE STRUCTURE AND QUALITY

To study the structure and components of concrete is the top concern for the improvement of the concrete quality and the quality and mix proportion design of the raw materials of concrete.

A. Structure and Components of Concrete

Different categories of concrete have different structures. Their mix proportion and array are different, such as fine and non-fine concrete.

1) Concrete with Suspended Compact Structure

Concrete of the kind is made up of mixture of continuous grading property. It is relatively company because materials of certain number array continuously from the large ones to the small ones. In fact, the large grains are squeezed apart by the small grains. The compactness and strength of the concrete of the structure are the highest.

2) Concrete with Aggregate Framework Pore Structure

Coarse aggregate instead of fine aggregate accounts for a larger percentage in the concrete of the structure. The pores between large grains cannot be filled. The pore of the concrete of the structure is relatively large and its strength is lower, but its penetration performance is good.

3) Concrete with Aggregate Framework Compact Structure

Concrete of the kind is a combination of the concrete of the above two kinds. The aggregate framework is still made up of adequate amount of coarse aggregate. There is also fine aggregate in the aggregate pores. Therefore, concrete of the kind boasts the optimal mechanical property.

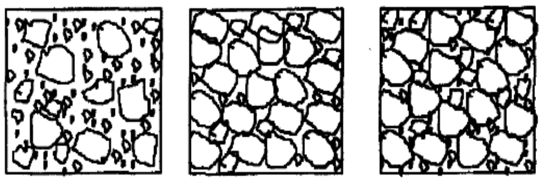

Figure. 1 Suspended compact structure, aggregate framework pore structure and aggregate framework compact structure.

The main components of non-fine concrete include cement, coarse aggregate and water. There is no fine aggregate, so its penetration performance is good. Concrete of the kind is mainly cement paste covering the surface of the coarse aggregate. The cement paste is glued together to form the pore structure. Concrete of the kind and structure has an aggregate framework pore structure similar to that of the ordinary concrete.

The relation curve between the stress and the strain of the pressed concrete can be expressed through the following mathematic equations:

$$When \varepsilon_c \le \varepsilon_0, \sigma_c = f_c\left[1-\left(1-\frac{\varepsilon_c}{\varepsilon_0}\right)^n\right] \quad (1)$$

$$When \varepsilon_0 \le \varepsilon_c \le \varepsilon_{cu}, \sigma_c = f_c \quad (2)$$

$$n = 2 - \frac{1}{60}(f_{cu,k} - 50) \quad (3)$$

$$\varepsilon_0 = 0.002 + 0.5(f_{cu,k} - 50) \times 10^{-5} \quad (4)$$

$$\varepsilon_{cu,k} = 0.0033 - (f_{cu,k} - 50) \times 10^{-5} \quad (5)$$

Where, σ_c stands for the pressure stress when the concrete's compressive strain is ε_c ; f_c for the designed value of the axial compressive strength; ε_c for the compressive strain of the compressed concrete; ε_0 for the concrete's compressive strain when the concrete's compressive stress reaches f_c (If ε_0 is turned out to be smaller than 0.002, 0.002 is regarded as the value of ε_0); ε_{cu} for the concrete's limit compressive strain (When the pressure is uneven, adopt Eq. (5) for the calculation; if the value of ε_{cu} is larger than 0.0033，0.0033 is regarded as the value of ε_{cu} ; In terms of axial compression, the value is ε_0)； $f_{cu,k}$ for the cube compressive strength of the concrete; n for the coefficient (when n is turned out larger than 2.0, 2.0 should be adopted as the value.)

III. THE RELATION BETWEEN THE STRUCTURE AND COMPONENTS OF THE CONCRETE AND ITS QUALITY

Cement, stone and sand are the major components of concrete of any kind. To control the raw materials of concrete can contribute to the quality of concrete, which is important to study the relation between the quality of concrete and its raw materials.

A. Raw materials

1) Cement

In recent years, China has accelerated the merging and reorganization of the cement industry by planning to eliminate the backward cement production capacity such as mechanical shaft kiln before 2017, and focusing on innovating relevant mechanisms and systems and enhancing the comprehensive strength of the cement industry [1].

There is a functional relationship between the concrete's dry shrinkage rate and the volume of the cement past in the concrete. In order to study the influence of cement on the quality of concrete, the volume of cement paste is changed for the observance of the changes of the concrete's dry shrinkage rate. Through the experiment, it can be seen that, when the cement content is higher, the concrete shrinkage value also increases. When the cement volume decreases, the concrete's dry shrinkage rate also reduces. (See Figure.2)

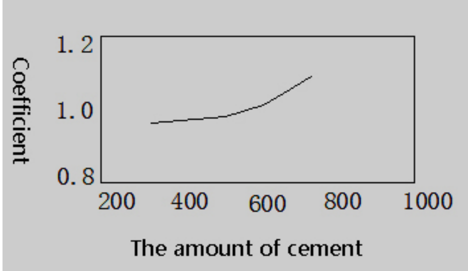

Figure.2. The cement content and concrete shrinkage.

The cement fineness has certain influence on the cement strength. The finer the cement is, the smaller the pore is in the paste, the shorter the induction period is for the cement spray, the more significant tee cement hydration thermal reaction is, the more compact the cement is and the greater the elasticity modulus is. If the cement fineness is relatively small, the cement will have a greater demand for cement and the cement strength will be reduced. The cement setting time can directly influence the quality of concrete. When the setting time is too short, it will influence the construction of the follow-up engineering. If the setting time is too long, it will influence the engineering progress. Lots of practices have suggested that the addition of certain amount of dehydrate gypsum in the manufacturing of cement can exert a great influence on the cement setting time. However, the cement temperature should be controlled to prevent overheating and the dehydration of dehydrate gypsum to form anhydrite, which might lose the regulating effect of the cement setting time.

2) Fly-ash

Fly-ash is a common mineral additive in concrete. The finer the fly-ash is, the larger the superficial area is and the more significant the activity of the fly-ash is. Many experiment results have suggested that the fly-ash fineness can greatly impact the concrete strength in the early period. The influence of the grains in the fly-ash whose grain size is smaller than 10μm on the concrete strength is greater than that of the cement on the concrete. Differently, monox has a great influence on the concrete strength in the later period. (See Figure.3)

The fly-ash fineness can also greatly influence the water content of the concrete. Within certain scope, the finer the fly-ash is, the greater the fly-ash fineness can influence on the working performance of the fly-ash. In terms of different amounts of loss on ignition (LOG), there exists certain functional relationship between the fly-ash fineness and the water demand of the fly-ash concrete. When LOG is controlled with 3%~4%, the functional relationship is: Y=88.76+0.25x; when LOG is controlled within 5%~11%, the functional relationship is: Y=89.32+0.38X (the correlation coefficient is 0.85).

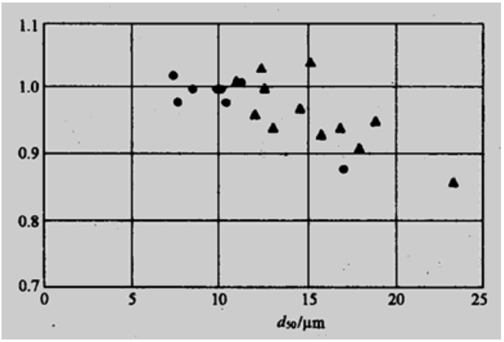

Figure.3 The influence of additives on the concrete strength.

3) Aggregate

Aggregate is the granular discrete material used for the preparation of concrete or motar. It can be divided into fine aggregate and coarse aggregate.

Fine aggregate is an important raw material of concrete, which accounts for a relatively higher percentage in the concrete volume. According to the practical situation, fine aggregate of different grading should be adopted for the preparation of concrete for different purposes. Besides, specific measures should be formulated to prevent the dissolution of concrete. Lots of facts have suggested in the blending of concrete the optimum plan is to choose coarse aggregate with relatively good grading. In the practical applications, due to the limit of various conditions, the fine aggregate can also be chosen but the fineness modulus should not be larger than 2 [2].

In the current practical applications of concrete, the pump concrete fine aggregate optimum grading chart is shown in Figure. 4.

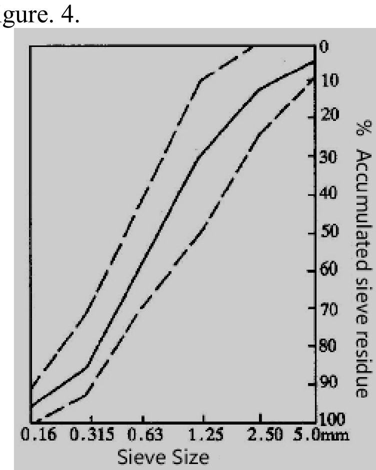

Figure.4 Pump concrete fine aggregate optimum grading chart

The coarse aggregate acts as a framework in concrete. There is a close relationship between the maximum nominal grain size of the coarse aggregate and the protection layer of the concrete structure. The grain size should be ensured to be no larger than two thirds of the thickness of the concrete cover and not exceed three fourths of the minimum spacing between the reinforcing steel bars. In terms of the high-strength concrete and the above prestressed concrete, the minimum nominal grain size should be smaller than 25mm. According to different types of coarse aggregate, the strength is expressed by different compressive strength values. For example, when the coarse aggregate is the rubble, the compressive strength can be expressed by the compressive strength of the rock. At the same time, the ratio of the compressive strength grading to the concrete strength should be larger than 1.5:1. In the practical application, when C50 is adopted, the ratio of its compressive strength and concrete strength grade should be larger than 2.

During the pump concrete pouring process, concrete pumping tube plugging might often occur. In order to ensure the pouring quality of the concrete and the safety of the concrete construction structure, the coarse aggregate with good grading can be adopted to increase the pumpability and continuity of concrete and reduce the water content and cement content of the concrete to achieve the goal of reducing hydration heat. [3]

B. Raw materials mix proportion study

TABLE I MIXTURE DESIGN

Binder type	**Cement content**	**No.**	**Cement: fly-ash: aggregate**
Straight cement	5%	C	5:100
Cement fly-ash (CF)	3%	CF1	3:11:100
		CF2	3:6.2:100
		CF3	3: 3. 3:100

TABLE II MIXTURE COMPACTION EXPERIMENTAL RESULT

Mixture content	**Optimum water content (%)**	**Maximum dry density (g/cm^3)**
10%	3.6	3.35

TABLE III LEVEL FACTORS TABLE OF THE MIX STRENGTH PROPORTION OF 2.5~5 MM AGGREGATE SIZE

Level factors	**Cement-sand ratio(C/S)**	**Water-cement ratio(W/C)**
1	1:4	1/3
2	1:6	1/2.5
3	1:7	1:2.7
4	1:6	1:2.5
5	1:7	1:2.3

TABLE □ PLAN TABLE OF THE MIX STRENGTH PROPORTION ORTHOGONAL EXPERIMENT OF 5MM AGGREGATE SIZE

Experiment No. Factor column No.	**2 Water-sand ratio (W/S)**	**1 Cement-sand ratio (C/S)**
1(1)	1:4	3:1
1(2)	1:4	3.2:1
1(3)	1:4	7.5:1

1(4)	1:5	9:1
1(5)	1:5	11:1
1(6)	1:5	3:1
1(7)	1:5	3.2:1
1(8)	1:5	7.2:1
1(9)	1:5	10.5:1
1(10)	1:5	10.7:1
1(11)	1:6	2.7:1
1(12)	1:6	5:1
1（13）	1:6	7.4:1
1（14）	1:6	9.8:1
1（15）	1:6	10:1

TABLE □ LEVEL FACTORS TABLE OF THE MIX STRENGTH PROPORTION EXPERIMENT OF 5～10 MM AGGREGATE SIZE

Level factors	**Cement-sand ratio (C/S)**	**Water-cement ratio (W/C)**
1	1:4	1/3
2	1:6	1/2.6
3	1:7	1/2.3
4	1:7	1/2.9
5	1:6	1/2.7

TABLE □. PLAN TABLE OF THE MIX STRENGTH PROPORTION ORTHOGONAL EXPERIMENT OF 5～10 MM AGGREGATE SIZE

Factors column No. Experiment No.	**1 Water-cement ratio (W/S)**	**2 Cement-sand ratio (C/S)**
2（1）	1:4	3:1
2（2）	1:5	3.3:1
2（3）	1:4	6.5:1
2（4）	1:4	9.7:1
2（5）	1:5	9.9:1
2（6）	1:5	3.2:1
2（7）	1:5	6.5:1
2（8）	1:5	7.5:1
2（9）	1:5	9.0:1
2（10）	1:5	10:1
2（11）	1:5	3.2:1
2（12）	1:5	4:1
2（13）	1:6	6.4:1
2（14）	1:6	8.7:1
2（15）	1:7	9.6:1

Among the components of concrete, cement, water and mixture play an important role. The mixture contains the aggregate and binder. The proportion of the two is relative among the components of the concrete, and can be mixed. Different proportions might lead to different results.

(1) Conduct a vibration (or tamping) experiment of the aggregate of certain grading without adding any binder, test the density under the vibration condition and calculate the porosity of the aggregate:

$$V_k = 1\text{-pz / Ps} \quad (6)$$

V_k stands for the porosity of the aggregate;

Pz stands for the tap density of the aggregate (g/ cm^3);

Ps stands for the apparent density of the aggregate (g/ cm^3).

(2) According to the porosity obtained, the aggregate volume and mass are obtained. Fill the volume with the binder of the optimum water content under the compaction condition, and the following equation can be obtained:

$$V_j = 1 - V_k \quad (7)$$

Vj stands for the aggregate volume (cm^3)

$$Mj = Vj * pz \quad (8)$$

M_j stands for the aggregate mass (g)

(3) According to the above two equations, the volume and mass of the binder can be obtained:

$$V_h = V_k \quad (9)$$

v_h stands for the binder volume (cm^3)

$$m_h = V_h * \text{P h} \quad (10)$$

P_h stands for the binder density (g/ cm^3)

m_h stands for the binder mass (g)

Generally speaking, the semi-rigid materials need the binder whose proportion is not too low. To avoid the embrittlement of the concrete, binder of a high content cannot be used. Besides, the extension strength of all materials and the strength meeting the load requirement are decided by the practical proportion of binder.

The following experiment can be conducted to prove the function of binder proportion in concrete.

According to the research goal, seven mixtures are adopted. (See Table 1) For example, the first mixture adopts the pure cement as the binder, the proportion of the cement and the fly-ash is 5:100. There is almost no aggregate. However, when the binder is the cement fly-ash, there are seven experimental samples of different proportions of cement, fly-ash and aggregate.

Then number them for the convenient of preparing mixtures of different proportions and studying the concrete design methods. Then the experimental method is designed according to standards. For example, the standard method is adopted for the CF. Recommend the limit for the aggregate framework compaction grading. Then they are numbered CF1, CFA and CF3 according to the components of different mixtures. The design result is shown in Table 2.

Among the major factors influencing the non-fine concrete strength, the most common factors, such as W/C and C/S are adopted as the parameters of the mix level orthogonal experiment. A comparative experiment is conducted of mixtures of different grains. This paper will not give an elaborate description of the experimental plan and results. Please refer to Table 3 and Table 6 for examples.

Based on the analysis of the data and table, it can be see that, the smaller the aggregate size is, the larger its general specific surface area is. The two are in an inverse proportion. When all the aggregates call for a greater amount of cement paste, the cement content also increases. The two are positively correlated to each other. Therefore, the concrete whose aggregate size is small calls for a greater amount of cement. In other words, high C/S can ensure the concrete quality.

The experimental data also reminds the author that to increase the aggregate content in the mixture and exceed the content limit of the aggregate in the loose aggregate framework can reduce the shrinkage coefficient and improve the crack resistance and anti-fatigue performance of the mixture, namely the concrete quality.

Ⅳ. CONCLUSIONS

Therefore, to control the quality of the raw materials can fully ensure the quality of the concrete.

A. The choice of raw materials

The compressive strength of the coarse aggregate is low, whose general compressive resistance grade is 42.5. Therefore, the ordinary Portland cement should be preferred.

In the above experiment, it can be seen that the aggregate type has a great influence on the concrete compressive strength, which is one of the most important factors. In order to improve quality, ordinary concrete usually adopts aggregate of a high grading. The total aggregate content used by $1m^3$ concrete is in line with the value of the close packing density, which is generally 1,200kg~1,400kg.

B. Choice of the proportion rate

In preparing concrete, the cement content should be chosen according to different grain sizes. The stone computing method follows the method of the close packing density. The proportion of the water content and the cement content is mainly based on the whether the cement paste can evenly attached to the surface of the aggregate without forming flows. In order to better ensure the water permeability, the W/C ratio should be within 0.30~0.42.

If the grain size is the same, the improvement of the concrete strength is decided according to the increase of the cement content. When the cement content reaches certain amount and the cement paste cannot evenly distribute on the cement surface, it is necessary to add the proportion of water in cement. Thus, it can be seen that small W/S ratio and more water content can improve the concrete compressive strength.

To sum up, the transformation of the concrete to the diversified model can promote the rapid development of the concrete industry to some extent. In order to ensure the concrete quality, it is necessary to choose the raw materials in line with the technical requirements and enhance the analysis of the hazardous substances and technical indexes of the raw materials. The analysis is of vital significance to study the relation between the concrete quality and the raw materials and the improvement of the concrete quality.

ACKNOWLEDGEMENTS

This work is supported by the Scientific Research Program Funded by Shaanxi Provincial Education Department, China (No.15JK1122),and Shaanxi University of Technology research projects, China (No.SLGQD13(2)-20).

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