Design of concrete mix ratio and the influence of high water absorption resin and water reducer on strength and working performance

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Abstract. The performance of concrete and water cement ratio, water ratio and unit water consumption has a close relationship, concrete mix ratio design is actually to determine the proportion between the three, correctly determine the proportion relationship, can make concrete meet the design requirements. This paper systematically studies the working performance of concrete with different strength grades, and then compares the experimental results with the four concrete strength grades designed. High water absorption resin process increases the tightness of the slurry, to improve the working characteristics of cement, and then improve the durability of cement function. The influence of the high absorption resin curing agent and water reducing agent on different concrete strength and working performance is studied. The test data between high water absorption resin and absorbent are used to form the change curve of various strength grades, the interaction mechanism between high water absorbent resin and absorbent is analyzed, and puts forward an important scientific basis for the study of cement mix ratio.

Keywords: Mix ratio design, high water absorbent resin, concrete strength, concrete working performance, water reducing agent.

1. Introduction

Cement is also in the infrastructure construction construction, more common and considerable use of construction materials, concrete characteristics and how to adapt to the construction conditions, and its configuration quality is closely related to a great relationship.The configuration of different material ratios in concrete can improve the construction characteristics of concrete, but also can better adapt to the construction conditions.The water reducing agent can produce the corresponding flocculent structure, can improve the fluidity of concrete mixing material high absorbent resin material, is a new functional polymer material developed in recent years.It has not only good extraction and rain resistance characteristics, but also has the characteristics of polymer plastic, with excellent construction characteristics and use performance, has been used in industry, agriculture, food, medical care, health, daily necessities, and environmental protection buildings and other aspects.The internal maintenance process of high water absorption resin is the latest trend in the development of concrete process in recent years, which is an important reform for high strength and high performance concrete process, and has a great impact on improving the efficiency and durability of buildings.

2. Experimental materials and methods:

2.1 Experimental Materials

Experimental raw materials include cement, sand, gravel, admixture, water [1], etc.:

1. Cement: P.O42.5;
2. Sand: river sand (medium sand);
3. Gravel: 5-31.5mm continuous grain size;
4. High water absorption resin;
5. High-performance water-reducing agent

1.2 Experimental Methods:

Using quality method, four concrete strength grades C30, C35, C40, C50;

Make a concrete test piece of 100*100*100mm.

(1) Determine the preparation strength (fcu, 0):

Table 1. standard deviation

Concrete strength standard value	≤C20	C25-C45	C50-C55
standard deviation	4.0	5.0	6.0

The design strength grade of the concrete in this experiment is less than C60, and the standard deviation of 5.0 and 6.0 is determined according to Table 1.

Since the design strength level of the original test concrete is, the strength of type C60 is calculated according to the following formula:

fcu, 0=fcu, k + 1.645σ

The preparation strength of different concrete strength grades in the following table is obtained:

Strength grade	C30	C35	C40	C50
Preparation intensity	38.225MPa	43.225 MPa	48.225 MPa	59.870 MPa

(2)Determine the water-to-ash ratio:

Because the coarse aggregate selected in this experiment is gravel, According to the following table, the regression coefficient α_b α_a was 0.53 and 0.20, respectively.

Table 2 Table of regression coefficient values

Coarse aggregate varieties	gallet	scree
Coefficient aa	0.53	0.49
Coefficient ab	0.49	0.13

The water-glue ratio is calculated according to the following formula:

$$\frac{W}{C}=\frac{\alpha_a \bullet f_{ce}}{f_{cu,0}+\alpha_a \bullet \alpha_b \bullet f_{ce}}$$

Table 3 Water-glue ratio

Strength grade	C30	C35	C40	C50
Water glue ratio	0.38	0.39	0.40	0.41

(3)Determine the water consumption per unit of concrete:

Check the unit water consumption table to determine:

Table 4 Water consumption

Strength grade	C30	C35	C40	C50
Water consumption per unit	175	180	175	175

(4)Determine the amount of cement:

The amount of cement is calculated by the above water consumption and water-cement ratio:

$$m_{b0} = \frac{m_{w0}}{W/B}$$

Table 5 Quantity of cement used

Strength grade	C30	C35	C40	C50
Cement dosage	461	462	438	427

(5)Select the sand rate:

Since the slump is between 10mm to 60mm, the sand rate can be determined according to the following table:

Table 6 Sand rate of concrete

Strength grade	C30	C35	C40	C50
Sand coarse aggregate ratio	30%	30%	30%	30%

(6)Amount of coarse and fine aggregate used:

The total capacity of coarse and fine cement in this experiment was determined by the quality method [2]:

Using the following formula, the following:

$$m_{f0} + m_{c0} + m_{g0} + m_{s0} + m_{w0} = m_{cp}$$

$$\beta_s = \frac{m_{s0}}{m_{g0} + m_{s0}} \times 100\%$$

Table 7 Matratio

Strength grade	Water glue ratio	Cement dosage	The amount of gravel	Water consumption	Sand dosage
C30	0.38	461	1200	175	514
C35	0.39	462	1196	180	512
C40	0.40	438	1216	175	521
C50	0.41	427	1224	175	524

Calculate:

C30: Mg＝1200kg The amount of fine aggregate Ms＝514kg mix proportionMc:Mw:Ms:Mg＝1:0.38:1.11:2.60

C35: Mg＝1196kg The amount of fine aggregate Ms＝512kg mix proportionMc:Mw:Ms:Mg＝1:0.39:1.11:2.81

C40: Mg＝1216kg The amount of fine aggregate Ms＝521kg mix proportionMc:Mw:Ms:Mg＝1:0.40:1.19:2.78

C50: Mg＝1224kg The amount of fine aggregate Ms＝524kg mix proportionMc:Mw:Ms:Mg＝1:0.41:1.23:2.87

When mixing the cement according to the calculated cement matching ratio, fill the cone cement cylinder with it and lift it in the vertical direction to measure the elevation difference between the height of the cylinder and the highest place of the collapsed cement, that is, the slump difference of the cement mixture, in mm.

Table 8 Slump degree

Strength grade	C30	C35	C40	C50
Slumps （mm）	25mm	32.5mm	15mm	27.5mm

2.2 Analysis and discussion of the experimental results：

2.1.1Comparing the working performance of concrete of different strength grades according to the concrete mix ratio

Based to the slump of the four concrete strength grades：

The higher the slump is, the greater the fluidity of the mixed material in the cement.It is concluded that concrete mix of C35 strength grade has the strongest mobility, while C40 strength grade concrete mix has the least mobility, and C30 and C50 strength concrete mix grades have the lowest mobility.That is, C35 strength grade concrete working performance is the best, while C40 strength grade concrete working performance is poor.[3]

2.1.2 The concrete strength development curve of the four strength grades was fitted with a function f_n = Algn =(n take 7d and 14d)

Table 9 Concrete strength comparison from 7 days to 14 days

Strength grade	C30	C35	C40	C50
7d compressive strength	31.4	35.7	39.8	49.5
Compressive strength of the 14d	35.6	40.6	45.2	56.2

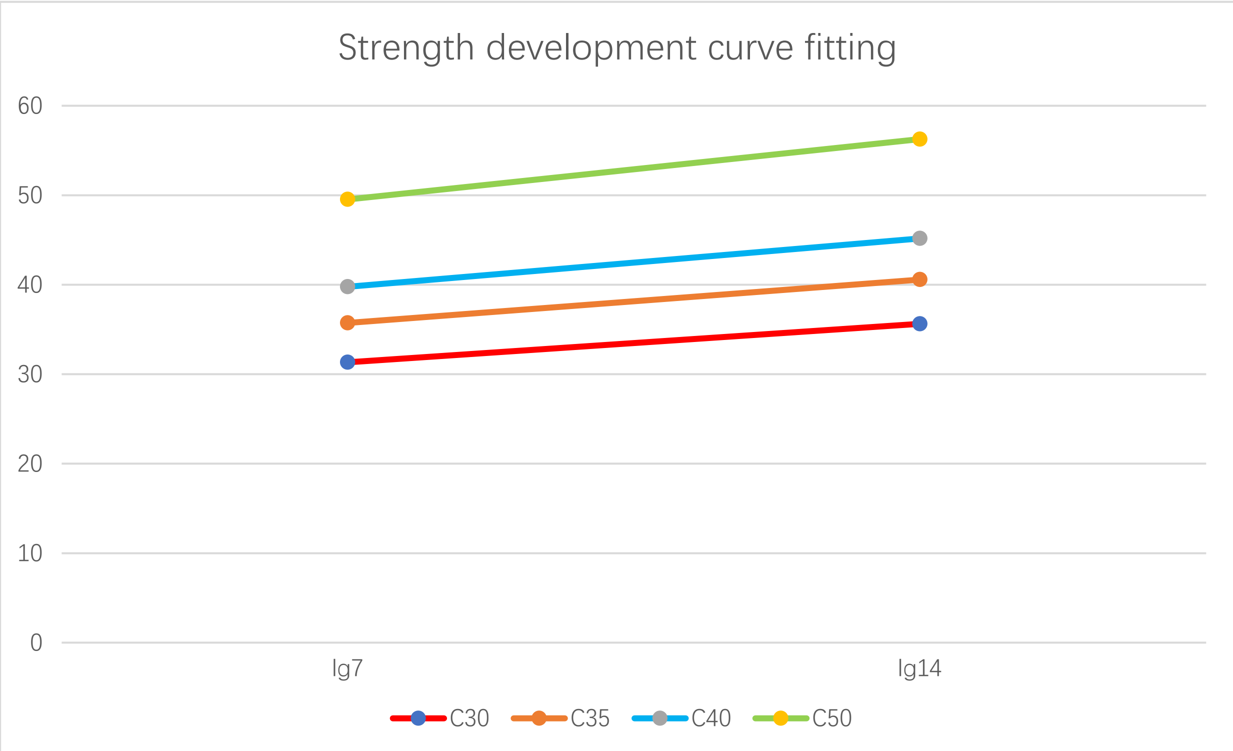

Figure 1. Strength development curve

The calculated A of each intensity grade is:

Table 10 Calculated value A

Strength grade	C30	C35	C40	C50
A	14.28	16.08	17.94	22.39

Correlation coefficent R^2=1

2.1.3 Based on fce, the regression coefficient of cement and crude aggregate of the measured value of the compressive strength of concrete at the same age and fcu, the measured value of concrete and crude aggregate is derived.

The regression coefficients A and B are obtained according to $f_{cu} = Af_{ce}(\frac{C}{W} - B)$:

A=0.751
B=0.772

When the concrete strength is 47Mpa, according to $f_{cu} = Af_{ce}(\frac{C}{W} - B)$:

The mix ratio is: Mc:Mw:Ms:Mg=1:0.48:1.40:2.81

2.1.4 Effect of high absorption resin curing agent on different concrete strength and working performance:

Add + 1% high water absorption resin internal curing agent (SAP) (50 times pre-absorbed water) to the above four strength grades, maintain under standard conditions for 7 and 14 days, measure their compressive strength and compare the difference in the compressive strength of the concrete mixture in the absence of curing agent.

Table 11 with any added SAP intensity comparison

Concrete	1%SAP		No admixture	
	7d compressive strength (MPa)	Compressive strength of the 14d (MPa)	7d compressive strength (MPa)	Compressive strength of the 14d (MPa)
C30	32.0	36.3	31.4	35.6
C35	36.7	41.6	35.7	40.6
C40	40.8	46.3	39.8	45.2
C50	49.4	56.1	49.5	56.2

SAP high water absorption resin is a high polymer material with high water absorption ratio. Its internal space is a mesh structure, and this characteristic can absorb and store water. When the osmotic pressure with the external solution changes, water will be released to improve the relative humidity inside the concrete, so as to achieve the effect of internal maintenance.[4]

Working mechanism of SAP high water absorption resin: when SAP is added to concrete, gel holes and small pores increase, the size of large pores and pores in concrete decreases, refining the concrete hole structure; there is a layer of film material inside the pores.Volume shrinks after water loss and eventually forms a thin-film packing structure from an expanding three-dimensional mesh.On the outside of the pore wall, hydrated products interlace each other with fewer pores and relatively dense structure. SAP particles provide water supply for the growth of hydration products, effectively preventing the volume shrinkage caused by water loss in concrete, thus improving its compactness.[5]

The mechanism of SAP to improve the early cracking and shrinkage performance of concrete is that the absorption and desorption of SAP particles, the hydrogen bonding of partially absorbed water and polymer chain, and the surface film formation of SAP particles delay the loss of water and change the internal humidity state and distribution of concrete.[6]

SAP high water absorption resin effect: concrete self-shrinkage, dry shrinkage, plastic cracking performance shows a reduced trend, concrete frost resistance, chloride ion permeability has been significantly improved, improve the compaction degree of slurry, so as to improve the durability of concrete.[7]

According to the experimental data analysis: with the increase of SAP incorporation, the slump of concrete increases, the slump loss decreases, the gas content and pressure leakage increase, and the condensation time is slightly extended.SAP has little change in C30 strength grade, and the biggest change in C50 strength, which improves the strength and durability of concrete.

2.1.5 Effect of water reducer on the strength and working performance of concrete

The water reducer is added to the above four strength grades and maintain under standard conditions for 7 and 14 days to measure their compressive strength and compare the difference in the compressive strength of the concrete mixture without admixture.

Table 12 Comparison of whether adding water-reducing agent

concrete	Water reducer		No admixture	
	7d compressive strength (MPa)	Compressive strength of the 14d (MPa)	7d compressive strength (MPa)	Compressive strength of the 14d (MPa)
C30	29.3	33.3	31.4	35.6
C35	35.0	39.7	35.7	40.6
C40	40.3	45.8	39.8	45.2
C50	51.6	58.6	49.5	56.2

Working principle of water reducing agent: diffusion action: when the concrete adds water, because the cement slurry forms a flocculation system, without the lubrication process of natural flow, so affecting the fluidity of the concrete mixture.In the addition of water reducer, because the water reducer substance can be directional absorbed on the surface layer of concrete particles, so that the surface layer of concrete particles has the same charge, thus due to the electrostatic drive rejection effect, leading to the diffusion of concrete particles, flocculation system rupture, thus effectively improve the fluidity of concrete mixture.[8] lubricant effect: due to the high polarity of the hydrophilic base in the water reducing agent, the water reducing agent absorption layer in the concrete particle surface produces a new solvent water film, which produces a good lubricant effect, so that the fluidity of concrete is improved. The [9] water reducer substance is mainly composed of oleophilic group and hydrophobic group. Lyophilic groups point mainly to solution, while hydrophobic groups point mainly to air. When in contact with the concrete particles, the adsorption layer begins to overlap, keeping the concrete slump well. After the water in the flocculation tissue is automatically produced, the concrete particles are completely diffused, and increases the lubrication of the concrete particles surface, increases the hydration range of the concrete, and greatly increases the hydration rate.[10]

The effect of water reducing agent: improve the fluidity of concrete mixture, and then improve the working characteristics of concrete mixture.

Analysis of experimental results: the water reducer has the least effect on C35 strength cement and the largest effect on C50 strength concrete.

3. Conclusion

(1) Concrete mixture of C35 strength is the strongest, concrete mix of C40 strength is the minimum, and concrete mixture of C30 and C50 strength are medium. That is, C35 strength grade cement performance is the best, while C40 strength grade cement performance is poor.

(2) Due to the increase of SAP doping, the collapse rate of cement increases, the loss of cement collapse rate is greatly reduced, the gas content and pressure effluent rise, and the solidification time is increased. SAP has little change in C30 strength grade, and the biggest change in C50 strength, which improves the strength and durability of concrete.

(3) Water reducing agent has less effect on cement of C35 strength grade; more effect on cement of C50 strength grade. Water reducer enhances the working stability and hardness of cement mixture.

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