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The performance study of the open channel concrete in cold area

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Abstract. The antifreeze & seepage of the open channel projects is the most significant part in the rural water-reducing irrigation system. The prerequisite of the concrete durability is to ensure the concrete strength unchanged, and the concrete strength directly affects the durability. Using the Orthogonal Experimental Design (OED) Method analyzed that the affection on the concrete strength by replacing the ordinary silicate cement with the compound cement,and adding the Polypropylene Fiber (PF), Fly Ash (FA), Water-reducing Agent (WA) into the concrete. It is seen that the effect on the concrete with using the FA and the WA is significant while the PF has little effect on it, and get the mix proportion of the open channel concrete in cold area.

Introduction

Sustainable development was the main way in the development of the agriculture. It was an increasing trend that numbers of the antifreeze & seepage channel projects should be constructed in the western aridsemiarid region. At present, there were more than 80% of the built channel projects which had not constructed with seepage prevention. It affected its working life, and needed to be repaired. And it resulted in the reducing of the project benefits, also made durability of the concrete down. Therefore, it was of the significant that studying the channel projects of antifreeze & seepage in the rural area. The problem of the concrete fissure was the most directed factor which affected the concrete durability. Data showed that it could significantly improve the ability of the concrete fissure prevention by adding some PF into the concrete[2][3]. However, the technology of the fiber used into the concrete was undeveloped , which needed more to study. There was the direct connection between the strength and the durability of the concrete. Research on the concrete durability, the precondition was that there was no change or little change in the concrete strength. It was also the primary purpose that improving the concrete durability. The fly ash concrete was one of the Green High Performance Concrete (GHPC). It is of the significant that research on the fly ash concrete which could be helpful to waste recycling, environment protection, ecological balance[4]. Therefore, it is necessary to study the property of the concrete and its using in such place as the Inner Mongolia Autonomous Region which was enriched with coal, and belonged to not the western severe cold area but the aridsemiarid region.

Experimental set-up and result

There are many factors in affecting the strength and ductility of the concrete, and the most important one was the Water-cement Ratio(WR). Due to the collapse degree of the channel concrete couldn't be too much high, we got the lower WR in the experience. And according to the region characteristics of the Inner Mongol, using OED to optimize the match ratio of the concrete by replacing the cement of ordinary silicate with the compound cement, and adding the PF, the FA, the WA in the concrete. And it lay a foundation for the later research on the concrete durability design and maintenance of channels in cold area.

Level-difference analysis The Table 1 below shows the data of the orthogonal experiment. The strength value of each experiment is decided by the average strength value of the three testing-pieces. The Table 1 showed that, the four factors in the chosen range can satisfy the required strength which was 30N/mm^2. Compared the strength of the nine testing-pieces, the 7th testing-piece was the highest, which reached to 46.1 N/mm^2, while the lowest was the 9th testing-piece, which valued 33.3 N/mm^2. And It declares that it was necessary to adjust the content of the concrete additive. The highest, the 7th, 46.1N/mm^2 , and the second highest, the 4th , and its followed one, the first testing-piece, all the WR were the lowest level--0.37, while the strength ranged the lowest level, the 9th testing-piece, and the second lowest one, the third testing-piece, and their followed one, the 6th testing-piece, the WR was the highest level--0.45. As it known, it was the conclusive factor of the WR in affecting the concrete strength.

Table 1 The concrete strength experimental analysis

Testing Number	Factors				Strength (MPa)
	WR(A)	PF(B)	FA(C)	WA(D)	
1	1（0.37）	1	3	2	39.5
2	2（0.40）	1（0.6kg/m^3）	1	1	43.1
3	3（0.45）	1	2	3	34.9
4	1	2	2（15%）	1	44.9
5	2	2（0.9 kg/m^3）	3（20%）	3	37.4
6	3	2	1（10%）	2	35.5
7	1	3	1	3（0.25%）	46.1
8	2	3（1.2 kg/m^3）	2	2（0.20%）	36.8
9	3	3	3	1（0.15%）	33.3
Ⅰ	130.5	117.5	124.7	121.3	Sum of level1
Ⅱ	117.3	117.8	116.6	111.8	Sum of level2
Ⅲ	103.7	116.2	110.2	118.4	Sum of level3
R	26.8	1.6	14.5	9.5	
X_1^-	43.5	39.2	41.6	40.4	$\sum X_i^-=351.5$
X_2^-	39.1	39.3	38.9	37.3	$X^-=39.1$
X_3^-	34.6	38.7	36.7	39.5	

Besides, the Table 1 showed the four factors sum of the strength in the three levels (Ⅰ, Ⅱ, Ⅲ)respectively and their level-difference(R). As the experiment shown, the level-difference in the four factors which affected the strength of the concrete range from the highest to the lowest was that, WR> FA> WA>PF. The level-difference of the WR was the highest, and the FA and the WA followed it, while the PF was the lowest, less than 1/10 when compared with the other factors. In the Orthogonal Experiment, the level-difference reflects the affection of the factors. Therefore, the WA and the FA were the main factors in affecting the strength of the concrete.

Chart analysis In the Orthogonal Experiment, the strength of concrete had changed as the factors and levels changed. As the Fig.1 shown, the concrete can do its best work when the WR was 0.37,the PF was 0.9kg/m^3, the FA was 15% and the WA was 0.2% respectively. And the influence of the PF on the strength of concrete was extraordinary low. The choosing of the level was depended by the concrete durability. On the other hand, the lower the WR, the better the strength of the concrete. However, it could impart on the construction progress and its quality if the WR is too low. The choosing of the WR should be matching the construction environment. After that, the best matching is A=Random, B=Random, C=15%, D=0.2%.

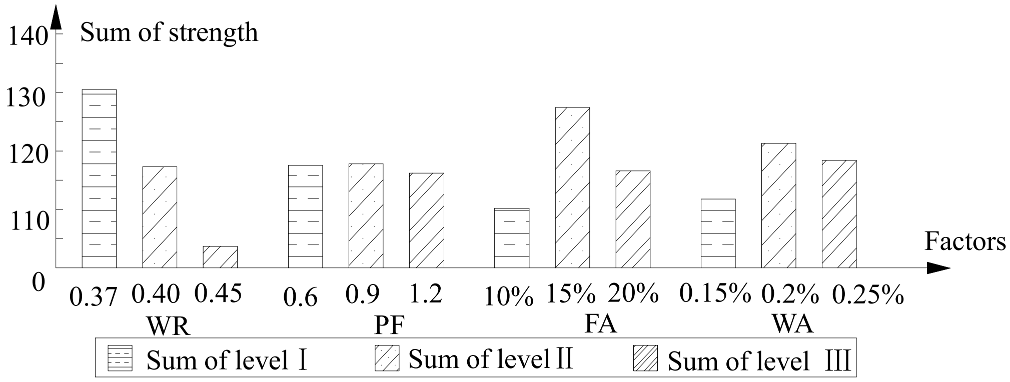

Fig.1 The trend graph of factors-strength

Variance analysis

1 Formulation of the Testing value[1]:

$$F_{A\sim E} = \frac{Q_{A\sim E}/(i-1)}{Q_E/(i\times j - j\times 2 - 1)} \qquad (i=1,2,3,\quad j=1,2,3,4,5) \tag{1}$$

$$Q_{A\sim D} = 3\sum_{i=1}^{3}(\bar{X}^{i}_{A\sim D} - \bar{X})^2 \tag{2}$$

$$Q_E = Q - Q_A - Q_B - Q_C - Q_D \tag{3}$$

$$Q = \sum_{i=1}^{9}(X_i - \bar{X})^2 \tag{4}$$

2 Significant discrimination[1]

$F \succ F_{0.01}$, very significant, marked with "**",

$F_{0.05} \prec F \le F_{0.01}$, more significant, marked with "*",

$F_{0.1} \prec F \prec F_{0.05}$, limited significant, marked with "(*)",

$F \le F_{0.1}$, not significant, marked with nothing.

Table 2 The variance test

Index	Variance Original	Sum of Squares	Degree of Freedom	Mean Square	F Value	Crisis Value	Mark
concrete strength	WR(A)	118.83	2	59.415	386.06	$F_{0.1}$（2,3）=5.46 $F_{0.05}$（2,3）=9.55 $F_{0.01}$（2,3）=30.8	* *
	PF (B)	0.5082	2	0.2541	1.65		
	FA (C)	36.15	2	18.075	117.45		* *
	WA (D)	15.27	2	7.635	49.61		* *
	Error(E)	0.4616	3	0.1539			
	Sum Total	171.22	11				

3 Results of the variance test

The Table 2 showed that, it was very significant of the WR influencing on the strength of the concrete, the FA and the WA as well. However, the PF had little influence on the strength of the concrete. Therefore, when choosing the best matching program of design for the concrete strength, we should particularly take the WR and the WA into consideration, and the PF could be taken appropriately. It was matching for the results of the level-difference analysis as well.

Table 3 showed the optimized mix proportion of the concrete, and it was less difference among the different concrete strength values when the WR was from 0.4 to 0.45. And the strength values were only reducing by 6.8%, and 52.8% more than the design value. The WR could take 0.45 when taking economical efficiency and application property into consideration. The PF had little influence on the concrete strength when the WR was 0.4. And the concrete strength got down by 1%. While the WR was 0.45, it got down by 2.1%. When taken the construction technique, the concrete durability, and the economic indicator into consideration, the optimized mix proportion of the concrete whose durability was the main factors was $A_2B_3C_2D_2$.

Table 3 Several concrete of the optimized mix proportion

WR	PF	FA	WA	Strength（28d）
0.4	0.6 kg/m^3	15%	0.2%	41.2MPa
	1.2 kg/m^3			40.8 MPa
0.45	0.6 kg/m^3			38.6 MPa
	1.2 kg/m^3			37.8 MPa

Conclusion

The WA is the decisive factor out of the four factors in affecting the concrete strength, which could be completely confirmed by the construction situations and the economic conditions. According to the characteristics of the Inner Mongolia region, when taken the construction technique, the economic conditions, add so on, the PF and the FA are the best choice to improve the concrete durability, while the PF has little influence on the concrete strength. Its value could be determined completely by the degree to the influence on the concrete durability. The FA and the WA has a significant effect on the concrete strength, and its levels should be considered appropriately. The optimized mix proportion of the channel concrete mainly with durability design is $A_2B_3C_2D_2$.

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