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Dynamic Mechanical Properties of Steel Fiber Reinforced Concrete Orthogonal Analysis

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Abstract. Through the research on the dynamic compressive strength of steel fiber reinforced concrete and comprehensive analysis of four factors: water-cement ratio, sand rate, steel fiber and steel fiber content types on kinetic properties of concrete, and further analysis of orthogonal test to find the optimal ratio of steel fiber reinforced concrete. Final conclusion: at low, medium and high strain rate, impact of SFRC dynamic compressive strength of primary and secondary factors are: sand ratio →steel fiber type → steel fiber content → water-cement ratio, water-cement ratio →steel fiber content → sand ratio→ steel fiber type, water-cement ratio →steel fiber content → steel fiber type →sand ratio. When the pressure is 0.3MPa, the optimal combination $A_2B_3C_4D_4$; when the air pressure is 0.35MPa, the best combination is still $A_2B_3C_4D_4$; when the pressure is 0.4MPa, the optimal combination is $A_2B_3C_4D_3$.

Introduction

Concrete materials are typically brittle materials, having a high compressive strength, and the tensile strength is relatively low. Steel fibers incorporated limits the formation and development of micro-cracks in concrete, cracks already formed act as a restraint, enhanced ductility of concrete [1]. Steel fiber reinforced concrete with high tensile strength, flexural, impact resistance and good toughness, a large number of domestic and international studies have shown that the steel fiber slenderness ratio, variety and content are the main factors affecting the mechanical properties of steel fiber reinforced concrete [2]. At present, the dynamic performance of steel fiber reinforced concrete material focused on the dynamic tension and compression, shock and anti-knock properties of [3-10].

Test Materials

In this paper, steel fiber concrete material component mainly including cement, aggregate thickness, water, steel fiber and water reducing agent. Performance four kinds of steel fibers shown in Table 1.

Table 1. Test of steel fiber performance indicators.

Steel Fiber Type	length（mm）	Aspect ratio	tensile strength
Straight type	33~36	40~50	≥600MPa
Pressure diamond	26~30	30~38	≥600MPa
Bow	39~41	52~55	≥1100MPa
Corrugated	38~42	36~45	≥750MPa

According to the requirements of the test, a total of two types of mold. SHPB test specimen using two Φ73.5mm × 36.5mm (each can be made six samples) homemade molds. Wash the mold before each use, and evenly coated with a layer of mineral oil in the mold.

Test Programs and Processes

SFRC Mix Design

SFRC mix design principles and orthogonal pilot program, the "absolute volume method" to determine the amount of material each group $1m^3$ steel fiber reinforced concrete.

Static Compression Test

In this paper, China University of Mining and deep MTS-815 electro-hydraulic servo rock mechanics testing system Geomechanics and Underground Engineering, State Key Laboratory test compressive strength of steel fiber reinforced concrete.

Dynamic Impact Test

SHPB rock dynamics test system used in this paper by the power loading unit, speed timing device, signal acquisition device, information processing and visualization system components, the material obtained in the higher strain range stress - strain relations, and control over their failure criterion failure process. In this paper, a total of 21 groups of steel fiber reinforced concrete specimens points 0.3MPa, 0.35MPa and 0.4MPa pressure three kinds of the dynamic mechanical properties test.

Experimental Results and Analysis

Dynamic mechanical test in three air pressure, range analysis and variance analysis to identify the relationship between the orthogonal factors and dynamic compressive strength of SFRC. Given four factors: water-cement ratio (factor A), sand ratio (factor B), steel fiber content (factor C), steel fiber type (factor D).

Range Analysis

Table 2 shows under the influence of various factors impact SFRC three kinds of pressure dynamic compressive strength poor results.

Table 2. According Rj size, you can compare the size of each of the three kinds of pressure factors influence.

	0.3MPa				0.35MPa				0.4MPa			
	A	B	C	D	A	B	C	D	A	B	C	D
T_{1j}	216.17	206.58	223.60	236.19	263.16	253.04	251.29	267.53	343.73	340.14	353.11	338.86
T_{2j}	246.15	240.13	209.59	204.80	292.38	265.60	240.04	248.67	385.10	354.08	325.40	355.08
T_{3j}	228.98	256.15	222.86	216.13	291.17	300.41	288.60	267.21	383.80	381.83	360.29	387.44
T_{4j}	211.57	200.00	246.81	245.75	225.68	253.34	292.45	288.98	307.98	344.56	381.81	339.23
R_j	34.58	56.16	37.22	40.94	66.69	47.37	52.41	40.32	77.13	41.69	56.41	48.58

When the pressure is at 0.3MPa, a significant degree of influence factors were B → D → C → A, Similarly, in the pressure of 0.35MPa and 0.4MPa when, respectively, A → C → B → D and A → C → D → B.

Analysis of Variance

Range analysis of the results of further calculations were obtained three kinds of pressure under each factor analysis of variance data shown in Table 3, Table 4, Table 5 below.

Table 3. 0.3MPa each orthogonal ANOVA under pressure impact analysis table.

Sources of variance	sum of square Q	DOF f	And mean square V	F
Factor of A	175.586	3	58.529	2.440
Factor of B	536.239	3	178.746	7.451
Factor of C	175.145	3	58.382	2.443
Factor of D	255.759	3	85.253	3.554
Error of e	280.480	3	93.493	
Sum of T	1205.253	15		

If a given level of significance, we can know that in the case of air pressure 0.3MPa, F value only factor B is greater than 5.39, that is, only sand ratio is significantly affected SFRC dynamic compressive strength, the factors affecting the rest of the test index was not significant.

In addition, factors A, C, F D value difference are not large, indicating that water-cement ratio, steel fiber content, steel fiber type three factors in this 0.3MPa pressure conditions, the dynamic compressive strength of steel fiber reinforced concrete the influence of the difference is not obvious.

Table 4. 0.35MPa each orthogonal ANOVA under pressure impact analysis table.

Sources of variance	sum of square Q	DOF f	And mean square V	F
Factor of A	736.281	3	245.427	10.230
Factor of B	373.664	3	124.555	5.192
Factor of C	520.703	3	173.568	7.235
Factor of D	203.687	3	67.896	2.830
Error of e	169.977	3	56.659	
Sum of T	2016.957	15		

Under air pressure 0.35MPa case, F value factors A, B, C, significant changes, where F value factor A and factor C is significantly improved, and greater than, F value factor B is decreased to a significant indicator of the following factors D F value is slightly lower, and still smaller. It can be seen, in this atmospheric conditions, water-cement ratio becomes compressive strength of SFRC dynamic impact on the dominant factors affect the ability of steel fiber content of the second; the more pressure is 0.3MPa, the influence of sand percentage of test indicators decline, become insignificant factors; steel fiber types still no significant effect on the test indicators.

Table 5. 0.4MPa each orthogonal ANOVA under pressure impact analysis table.

Sources of variance	sum of square Q	DOF f	And mean square V	F
Factor of A	1018.45	3	339.483	14.150
Factor of B	262.64	3	87.546	3.649
Factor of C	406.64	3	135.546	5.650
Factor of D	390.42	3	130.142	5.425
Error of e	136.22	3	45.407	
Sum of T	2214.37	15		

Under pressure value is adjusted to 0.4MPa case, factors A, C, F D values were greater than 5.39, this time, the water-cement ratio, steel fiber content and type of steel fiber significantly affect the test index, compared with sand rate on the test index's influence continues to decline. It is noteworthy that, under the atmospheric conditions, the type of steel fiber influence is already very close to the steel fiber content, and influence over the rate of sand.

Comprehensive analysis of variance results of three under pressure, it can be seen at low, medium and high strain rate, impact of SFRC dynamic compressive strength of primary and secondary factors were: B → D → C → A, A → C → B → D, A → C → D → B, a result consistent with the range analysis.

Optimization Analysis

To find the optimal level and the optimal combination of experimental factors in the tests, analyze the relationship between the factors and indicators test, identify indicators with variables patterns and trends, the need to optimize the results of orthogonal test analysis. And the third chapter different static compression test, impact load, due to the different strain rates, the influence of various factors change, same kinds of factors optimal index is also somewhat different.

As can be seen from Table 6, when the pressure is 0.3MPa, the water-cement ratio 0.33, 37% sand ratio, 2.25% fiber content, the use of corrugated steel fibers, the best combination $A_2B_3C_4D_4$.

As can be seen from Table 7, when the air pressure is 0.35MPa, water-cement ratio 0.33, 37% sand ratio, 2.25% fiber content, the use of corrugated steel fibers, the best combination is still $A_2B_3C_4D_4$.

As can be seen from Table 8, when the pressure is 0.4MPa, water-cement ratio 0.33, 37% sand ratio, 2.25% fiber content, the use of steel fiber bow, the optimal combination $A_2B_3C_4D_3$.

Conclusion

(1) At low, medium and high strain rate, impact of SFRC dynamic compressive strength of primary and secondary factors are: sand ratio →steel fiber type → steel fiber content → water-cement ratio, water-cement ratio →steel fiber content → sand ratio→ steel fiber type, water-cement ratio →steel fiber content → steel fiber type →sand ratio.

(2) When the pressure is 0.3MPa, the optimal combination $A_2B_3C_4D_4$; when the air pressure is 0.35MPa, the best combination is still $A_2B_3C_4D_4$; when the pressure is 0.4MPa, the optimal combination is $A_2B_3C_4D_3$.

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