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Research Article

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Research on high concentration cemented filling materials in coal mine

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ABSTRACT

Filling mining is a common technology for coal mining under buildings. On the basis of analyzing paste filling mining, this paper puts forward high concentration cemented filling which fits modern Chinese coal mine production and studies high concentration cemented filling material for coal mining emphatically. Through analyzing and testing the slurry concentration, mixture amount of cement and burning ash's impact on the properties of filling materials, the paper concludes the concentration and mixture ratio of the components of high concentration cemented filling materials for mine production, develops the additive composition and its dosage. Through ring pipe test, the filling materials' transportation resistance loss was tested. All the above tests show that high concentration cemented material is: low transportation resistance, no bleeding, high filling body strength, good integrity and stability, solidification time 6 hours and strength is beyond 4Mpa after 28 days.

Key words: high concentration cemented filling material; filling mining; ratio of slurry; admixture; transportation resistance loss

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INTRODUCTION

Filling mining is an ideal method of mining coal resources under three circumstances with safety and high efficiency, improving degree of extraction and reducing environmental pollution. High concentration cement mining has characteristics as high demand for filling materials, long transportation distance and high demand on filling body[1-2]. Presently paste filling mining is widely applied in coal mine, its characteristics include high fine fraction proportion and high concentration in filling slurry, high strength and low compression rate in filling body, poor slurry flowability, high transportation resistance with 7-10kPa/m, pipeline jam easily occurs[3-9].

Given the disadvantages of paste filling material, the author and his team put forward to apply high concentration cement filling material to fill the goaf, forming underground coal mine high concentration cement filling mining tech [10], and this tech was widely promoted and applied with its characteristics as good flowability, low transportation resistance, high filling body strength and low compression rate. High concentration cement filling material is made of broken gangue as aggregate, 425# portland cement and burning ash as cementing material, in addition of water reducing agent, water retaining agent, early-strength agent and water. The above materials, after mixing in certain proportion, activating and stirring, form high concentration slurry with mass fraction 75%~80% and collapsed slump 220~260mm[11]. High concentration cement filling material is a kind of standard dispersion with thixotropic property. Size fraction and cement distribute uniformly with no fine and coarse particle layer phenomenon, under stirring, the solid dispersion of the slurry is diluted and obtains good flowability, low transportation resistance and is easy for piping which prohibits pipe jam; the slurry is homogeneous-like non newtonian fluid, presents as stable homogeneous-like fluid in pipe, velocity is in the laminar flow zone, no

segregation and precipitation in the transportation process, when slurry arrives in filling point, it doesn't bleed and obtains early-strength property; fine fraction material proportion increases obviously, specific surface area increases, porosity and compression rate decrease, the filling body obtains high strength, integrity and stability, the load-bearing function is made full use of, the roof and rock stability is maintained, the above properties adapt to the requirements of filling materials in coal mining, high concentration cement filling material has a broad application prospect in the future. Thus, adjusting the relation of the components and choosing the proper mixture ration and admixture is significant for this method's promotion and application.

EXPERIMENTAL SECTION

1 Influence of ratio on the high concentration filling body properties

The raw materials of the test include 425# ordinary portland cement, gangue provided by coal mine and burning ash provided by nearby power plant, the 3 materials are made into slurry with water under normal temperature. After stirring, the stirred slurry is placed in the 100mm×100mm×100mm standard metal mould and form several groups of standard test mould. After 1 day, stripping the mould, the testing block samples are placed in curing box for 1d, 3d, 7d and 28d under the circumstance that relative humidity is beyond 90% and temperature is about 20±2℃. After curing, non side limit compression strength test is conducted. 3 parallel tests are conducted in each group and the test result chooses the average value. NYL-300 compression test machine is applied in the test.

(1) Slurry concentration's influence on filling body properties

Ordinary portland cement as cemented material, the slurry with concentration of 76%、78%、80% respectively are tested for finding the influence on the filling body properties. From Table1 and Figure1, when cement and burning ash proportion is fixed in 10% and 20 %, with concentration increasing, the filling body's strength is increasing and collapsed slump is decreasing.

Table 1 Influence of different concentration on filling body properties

No.	Ratio/% Cement:burning ash:gangue	Concentration/%	Compressive strength/ MPa				Collapsed slump/cm
			1d	3d	7d	28d	
1	10：20：46	76	0.46	0.95	1.34	4.06	26.4
2	10：20：48	78	0.52	1.07	1.56	4.07	25.1
3	10：20：50	80	0.55	1.19	2.19	4.68	24.3

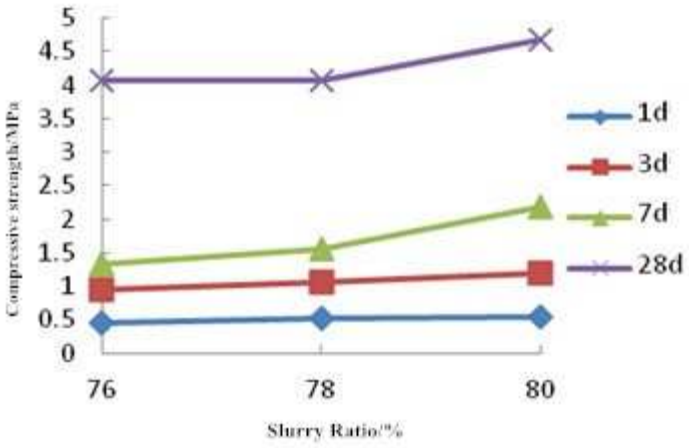

Fig.1 Influence of different concentration on filling body properties

(2) Burning ash dosage's influence on filling body properties

425# ordinary portland cement as cemented material, the concentration is fixed in 80%. The burning ash dosage is change and testing the dosage's influence of filling body properties, including compressive strength and collapsed slump. When the burning ash proportion is 10%, segregation and bleeding is severe, this test group is cancelled. Test result is shown in Table2. When burning ash proportion is 15%, bleeding is obvious and collapsed slump is proper. When burning ash proportion is 20%~25%, slurry water retention is proper and collapsed slump is moderate. When burning ash proportion is larger than 30%, collapsed slump is small. With burning ash proportion increasing, collapsed slump becomes smaller, water retention becomes better, showing that more burning ash leads to more fine fraction in slurry, water retention increases, flowability decreases, the change of filling body strength is not obvious and its strength peaks when burning ash proportion is 20%. As shown in Figure2, filling body strength is high in each age when burning ash proportion is 20%.

Table 2 Influence of different burning ash ratio on filling body properties

No.	Ratio/% Cement:burning ash:gangue	Concentration/%	Compressive strength/ MPa				Collapsed slump/cm
			1d	3d	7d	28d	
1	10：15：55	80	0.57	1.10	1.89	3.97	28.5
2	10：20：50	80	0.55	1.19	2.19	4.68	24.2
3	10：25：45	80	0.55	1.01	1.74	4.01	22.4
4	10：30：40	80	0.54	0.90	1.81	4.11	16.1

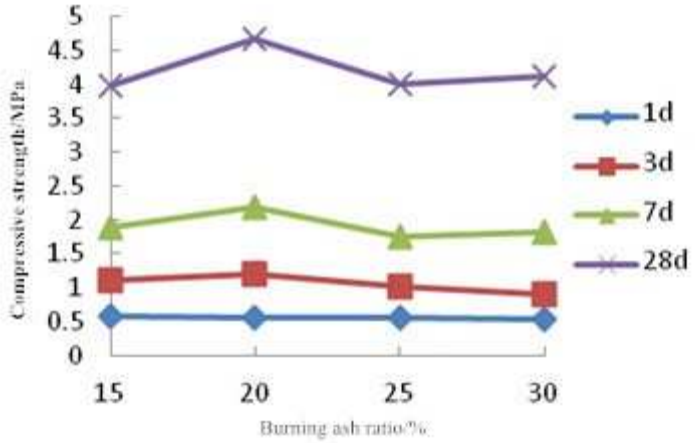

Fig.2 Influence of different burning ash ratio on filling body properties

(3) Cement dosage's influence on filling body properties

Ordinary portland cement as cemented material, when the concentration is 80%, cement dosage's influence on filling body properties is tested, test result is shown in Table3. As shown in Table3, when burning ash proportion is fixed in 20%, with ordinary portland cement proportion increasing, gangue proportion decreasing, slurry flowability increases and filling body compressive strength increases.

Table 3 Influence of different cement ratio on filling body

No.	Ratio/% Cement:burning ash:gangue	Concentration/%	Compressive strength/ MPa				Collapsed slump/cm
			1d	3d	7d	28d	
1	6：20：54	80	0.15	0.35	0.74	2.02	22.5
2	7：20：53	80	0.27	0.60	1.19	2.90	23.5
3	8：20：52	80	0.35	0.69	1.61	4.05	21.5
4	9：20：51	80	0.40	0.78	1.75	4.30	25
5	10：20：50	80	0.55	1.19	2.19	4.68	24.3

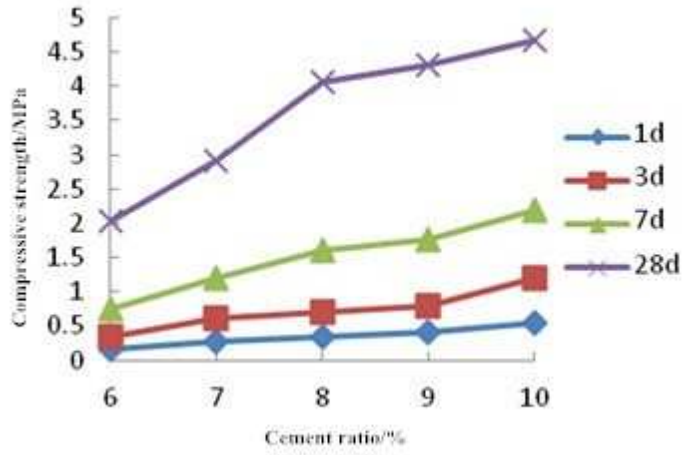

Fig.3 Influence of different cement ratio on filling body

In summary, the proper slurry ratio is concluded as ordinary portland cement: burning ash: gangue:

water=(8%~10%)：(20%~25%)：(46%~50%)：(20%~24%)，the collapsed slump is proper, flowability is good and strength is rational. Among the above ratio tests, the best one is ordinary portland cement: burning ash: gangue: water=10%：20%： 50%：20%.

2 Admixture's influence on filling body properties

Admixture is the core factor of filling material, which is capable of adjusting the performance index including filling material mechanic property, engineering property, setting time, water segregation, etc. The test on admixture is based on the filling slurry ratio of *cement: burning ash: gangue: water=10%：20%： 50%：20%.* The admixture dosage is percentage of amount of cement and burning ash.

(1)Water retaining agent test

Water retaining agent is the first admixture on test and is responsible for improving the properties of segregation, bleeding and settlement of filling material. As Table4 shows that when the dosage of water retaining is 0.06%, slurry segregation is obviously improved and bleeding rate is down to 0.2%. The conclusion is that water retaining agent dosage is fixed in 0.06% and the dosage is applied in the following tests.

Table 4 Influence of water agent on filling body's segregation and bleeding

Water retaining dosage	0.01%	0.02%	0.03%	0.04%	0.05%	0.06%	0.07%	0.1%
Segregation	Serious	Serious	Slight	None	None	None	None	None
Bleeding rate%	3.0	2.8	1.4	1.0	0.5	0.2	0.1	无

(2)Early strength agent test

To find an efficient and economic early strength applicable to filling material, 3 tests are conducted testing the flowability and setting time. Early strength agent acts as cemented material, so slurry ratio is as *cement: burning ash: water=10%：23%：20%,* then the properties are tested. As shown in Table5 early strength agent A and B performs good flowability and setting time meets the requirement. Considering in economic aspect, early strength agent A costs lower than B, so early strength agent A is the proper one for high concentration slurry.

Table 5 Influence of different early strength agent on slurry properties

Early strength agent	Dosage	Flowability/mm			Setting time	
		t=0	t=20min	t=50min	Initial	Final
Early strength agent A	0.5%	190	150	120	2.2	5.3
Early strength agent B	0.5%	190	160	120	2.25	5
Early strength agent C	0.5%	210	200	190	No setting	

(3) Admixture combined test

Early strength agent and water retaining agent can merely guarantee the suspension property and early strength, high concentration cemented filling places high demands on mould stripping time and final strength, coagulant and water reducing agent is needed to improve the slurry property to meet the requirement. After the dosage of early strength agent and water retaining agent is fixed, combined test is conducted to test the other admixture.

Gangue, burning ash and cement are made into slurry in accordance with the ratio generated from the high concentration cemented filling slurry test, the dosage of admixture is calculated on base of cemented material total amount, the target is testing slurry's collapsed slump, settlement time and compressive strength, whether the properties are ideal is through analyzing the test data, if all the indexes meet the requirement, the test is finished, the dosage of admixture is the most proper choice, if not, the admixture is adjusted and put into test again and again, the admixture dosage is optimized in this pattern till the most proper one is found.

Table 6 The dosage of admixture

Admixture	Water retaining agent	Water reducing agent	Coagulant	Early strength agent(ESA)	
				ESA A	ESA D
1	0.06%	0.5%	0.01%	0.5%	0.04%
2	0.06%	0.4%	0.02%	0.5%	0.03%
3	0.06%	0.3%	0.02%	0.5%	0.02%
4	0.06%	0.3%	0.03%	0.5%	0.02%
5	0.06%	0.2%	0.04%	0.5%	0.01%

Table 7 The filling material property test results under the condition of admixture

Admixture No.	Compressive strength				Collapsed slump	2h flowability	Molding time
	1d	3d	7d	28d			
1	Molding	0.31	1.05	3.22	260	High	＞4h
2	0.27	0.41	1.60	4.26	270	High	＜4h
3	0.52	1.10	2.15	4.70	275	High	＜4h
4	0.68	1.40	3.15	5.20	270	Common	＜4h
5	0.49	1.06	2.20	4.65	275	Poor	＜4h

Some conclusions are made from the test results, in the condition of applying No.1 admixture, filling slurry cannot be molding; To prohibit that conditions that filling production stops due to electricity, devices, etc., filling slurry needs to keep flowable within 2 hours, filling slurry doesn't obtain flowability when applying No.4, No.5 admixture; in the condition of applying No.3 admixture, filling slurry obtains good flowability and its compressive strength is larger than that of applying No.2 admixture, so No.3 admixture is the most proper admixture fits the present material.

3 High concentration cemented material transportation resistance loss

To test high concentration cemented materials flowability, ring pipe transportation test is conducted (ϕ 150mm), its transportation resistance loss is shown in Table8.

Table 8 Ring pipe transportation test

Slurry sample	Burning ash ratio	Concentration	On-way resistance loss （kPa/m）	Local resistance loss （kPa/m）
1#		78.0%	3.12	3.49
2#	18%	78.5%	3.89	4.36
3#		79.0%	5.43	6.08
4#		78.0%	3.70	4.14
5#	20%	78.5%	4.86	5.44
6#		79.0%	6.06	6.79
7#		78.0%	4.18	4.42
8#	22%	78.5%	5.74	6.42
9#		79.0%	7.54	7.84

From the data in Table8, the transportation resistance of high concentration cemented material is far smaller than that of paste filling material (7-10kPa/m), slurry flowability performs good ensuring the transportation safety and decreasing the pipe consumption. During ring pipe test, the slurry still keep pumpable after standing for 2 hours ensuring the flowability within 2 hours, which further decreases the probability of pipe jam during slurry transportation.

CONCLUSION

(1) Based on analyzing advantages and disadvantages of paste filling method, putting forward high concentration cemented filling mining technology, high concentration filling slurry is 75%~80% in concentration, slurry transportation resistance is small, filling body strength is high, slurry doesn't need dewatering, filling body's integrity and long-term stability is good.

(2) The proper high concentration cemented slurry ratio is as ordinary portland cement 8%~10%, burning ash 20%~25%, when the slurry ratio is during 75%~80%, slurry flowability is good, strength is proper, the best ratio is ordinary portland cement: burning ash: gangue: water is 10%：20%： 50%：20%.

(3) When the dosage is as water retaining agent: 0.06%, water reducing agent: 0.3%, coagulant: 0.02%, early strength agent A: 0.5%, early strength agent D: 0.02%, the slurry property is the best, collapsed slump>220mm, settlement time<6h, 28d compressive strength>4 MPa, high flowablity within 2h, small segregation, small bleeding and good mixablity.

(4) The transportation resistance of high concentration cemented material is far smaller than that of paste filling material, slurry flowability performs good, meeting the requirements for large flow and long distance transportation in coal mining; the suspension property and homogeneity is good that decreases the probability of pipe jam during slurry transportation and ensures the transportation safety.

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