The optimization ratio of filling materials solidify with fly ash and the analysis of its mechanical performance

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Abstract

In order to study the best ratio and mechanical properties of the fly ash cured filling materials, orthogonal method was exploited to test the fluidity, initial and final setting time and compressive strength of the cured material mixture of water, sodium silicate and slaked lime, we obtained the optimal ratio of fly ash cured filling materials. The results show that when the mass ratio of coal fly ash to cement is 1:1.5, the amount of sodium silicate reaches to 5% and the amount of hydrated lime 2%, fluidity of slurry and strength of solidified material well conform to the basic requirements of filling materials for closed wall in coal mine; uniaxial and triaxial compression tests were used to analysis the mechanical properties of best ratio of fly ash,Triaxial compression experiments show filled with fly ash material deformation and failure are divided into four stages: compaction stage, yield stage, the stage of plastic deformation and destruction stage; exhibits a linear elastic deformation stage and deformation characteristics of reinforced plastic stage, basically there is no softening stage.

Keywords

Cured with fly ash; filling materials; Optimization ratio; sealing wall; Uniaxial-triaxial compression; Stress-Strain

1. Introduction

After the completion of the coal mining, in order to prevent the mined out area due to leakage caused by the large area left coal oxidation caused by spontaneous combustion and to protect adjacent normal working face mining and need to timely to goaf are closed; for now mining working face, if because of fire prevention and control measures are not in place, the parameters of coal spontaneous combustion is not clear, but also easily caused by spontaneous combustion of coal. The goaf spontaneous combustion or air leakage in the working face governance reflects the fire prevention from passive control to change the concept of active prevention. Therefore, the choice of the material and the thickness of the closed wall is the precondition of the fire prevention and extinguishing effect when the sealing measures are taken.

Many scholars have conducted a lot of theoretical, experimental research and field application on the closed wall of the mined out area. Zhang Xinsheng, Li Quangui [1] for meters from the village of coal 260051 working face exist serious mining empty area of air leakage and spontaneous combustion problems, through RCL marl osteoporosis agent use and gob closure for air leakage blocking and anti combustion technology using, cut off the goaf air leakage channel, of mine goaf air leakage plugging, along the air Liu Xiang plugging the air and natural fire prevention has certain reference significance. Luo Zhenmin, Deng Jun, and other [2] for the limitations of the current mine closed wall in the application, a new type of mine used a new type of rapid explosion proof sealed wall. The material has the advantages of small volume, short construction time and long distance operation, and plays an important role in the safety production of the mine.

However, at present for sealing of goaf the cost of material itself and time-consuming, high labor requirement, the construction difference wall compressive property of closed, easy for cycle to pressure or mining quake in closed wall fracture, deformation, instability, cracks easily and roof of the leakage passage, easily caused spontaneous combustion. Based on this, many scientific research workers continue to study and optimize the airtight wall materials, and finally choose the fly ash based materials to fill the closed walls. Yong Fei Jin, to [J] developed a to cement and fly ash as aggregate new inorganic solidified expansive filling materials, non-toxic, plugging, expansion, compressive in one is a effective plugging leakage channel of new mine anti fire material. So that the cost and performance of the closed wall has been a revolutionary change, greatly improving the work efficiency of fire prevention. Advantages of Zi Bo Tang, de Shun Kong [4] using fly ash concrete have good physical and mechanical properties, design a kind of fly ash concrete fire proof seal wall, the confined wall with fast construction speed, low labor intensity of workers, the compressive strength can be adjusted, flexible strong, deformation capacity, good fire resistance, anti impact ability strong, wide popularization and application value.

In fly ash filling packing closed wall, filling material quality is good or bad will affect to pipelines and the effect of air leakage control. China's current coal mine fire prevention wall filling and sealing materials are mainly yellow mud, cement mortar, fly ash solidified materials etc.. However, these materials have the characteristics of high cost, low volume after dehydration, poor curing effect, low support strength and so on. Therefore, it is necessary to determine the mechanical properties and the law of stress and strain to determine the reasonable parameters of the closed wall. The experiments identified optimum ratio of solidifying fly ash filling materials and corresponding mechanical parameters, from the micro perspective analysis of the different forms of compressed under the action of fly ash solidified material should stress - strain characteristics and damage law, is in the closed wall key parameters of the numerical simulation to provide the basic data and the theoretical analysis basis.

2. Text Basic requirements for the performance of coal fly ash filling materials

At present, more and more research on coal fly ash is used for underground filling in coal mine at home and abroad. The ratio of filling materials determines the strength and mechanical parameters of filling materials, and also directly affects the effect of filling and plugging. Good filling materials require rapid solidification, high compressive strength and residual strength, and can resist certain impact and low cost. Fly ash used as base material of coal mine filling material, in order to guarantee the effect and cost of filling, solidifying fly ash filling materials must meet the following basic properties: (1) to achieve the conveying process requirements; (2) low cost of filling; (3) preparation ratio and simple process; (4) filling and sealing wall strength meet engineering standards. Through the field experiment, the result shows that the flow rate of the fly ash mixture is more than 130mm, and the flow effect is good, and there is no pipeline blockage phenomenon. In accordance with the provisions of the national standard setting time, the initial setting time of the ordinary concrete slurry must not be more than 2 min, and the final setting time shall be not more than 10h. In addition, the compressive strength of fly ash points for filling body of early strength and post strength, early strength generally need to fill the body to achieve self-reliance, their own strength to reach 0.5MPa; late strength is according to the actual situation of the scene (the weight of overlying strata, top floor support pressure and other parameters) is designed. Shanxi Yungang Mine according to the Bieniawski calculation method to determine the compressive strength of fly ash later reached 3.5MPa.

3. Optimization test of fly ash solidified material

3.1 material

The test of the fly ash from Baqiao power plant, the size of 110 ~ 230mm, the specific surface area of 2500 ~ 7000cm2/g. According to measurements, Baqiao power plant fly ash calcium low, according to the requirements of filling material preparation, at the beginning of the fly ash slurry curing final setting time of need within the scope of the provisions. The coagulation time and the curing strength of fly ash slurry are relatively large, and the curing effect is not ideal by using water glass. So as to control the cost of curing materials, the fly ash slurry was prepared by using hydrated lime and water glass as the curing agent.

3.2 method

In the test of mixing if study of factors and levels more, test times will greatly increase, in the actual project will experiment because of limited funding, and the test cycle is too long and give up design parameters, reduce the number of tests of the design parameters become an important research goal. Therefore, in order to control the curing cost, the total amount of the curing agent is controlled not more than 10% of the amount of fly ash, and the water cement ratio is 1:1.2 ~ 1:1.5, and the compound method is prepared by using hydrated lime to water glass, and the content of each component is shown in table 1.

Table 1 compounding ratio of raw materials and curing agent

Water cement ratio	water glass (%)	Hydrated lime (%)
1:1.2～1:1.5	2%～5%	2%～5%

3.3 Factors and levels of Proportioning Test

Due to the compound ratio, the water cement ratio, the water glass content and the amount of hydrated lime were determined by the amount of the fly ash slurry, the initial setting time and the compressive strength. Because of the need to measure the amount of more, and the level of complexity, in accordance with the conventional methods are prepared, at least 64 trials, spend a lot of cost and labor; and orthogonal method is simple, objective, orthogonal scatter, neat can ratio, and can greatly reduce the number of experiments. The results can be of high reliability, so the use of orthogonal method to meet the optimal ratio. The orthogonal design was used in this experiment, the water cement ratio, the water glass and the hydrated lime content were all taken 4 levels, and a total of 16 experiments were done.

3.4 Test ratio and its result analysis

On the basis of determining the factors and levels of the experiment, the corresponding test plan is established by using the orthogonal method. The orthogonal design table for the selection of the test plan is. Then test the different proportion of the program, the flow rate, the initial setting time and the compressive strength. Formula and test results are shown in table 2.

Table 2 formula and test results of fly ash solidified material

NUM	factor			Degree of	Initial final setting time		28d press
	A	B	C	flow /mm	Initial	setting	/Mpa
P01	1（1:1.2）	1（2%）	1（2%）	201	68	57	3.69
P02	1（1:1.2）	2（3%）	2（3%）	194	59	54	3.97
P03	1（1:1.2）	3（4%）	3（4%）	172	51	48	4.39
P04	1（1:1.2）	4（5%）	4（5%）	165	43	45	4.78
P05	2（1:1.3）	1（2%）	2（3%）	196	63	55	3.97
P06	2（1:1.3）	2（3%）	1（2%）	188	55	50	4.41
P07	2（1:1.3）	3（4%）	4（5%）	174	47	44	4.93
P08	2（1:1.3）	4（5%）	3（4%）	163	44	42	5.54
P09	3（1:1.4）	1（2%）	3（4%）	190	58	51	3.83
P10	3（1:1.4）	2（3%）	4（5%）	179	46	46	4.12
P11	3（1:1.4）	3（4%）	1（2%）	171	39	41	4.84
P12	3（1:1.4）	4（5%）	2（3%）	157	31	37	5.74
P13	4（1:1.5）	1（2%）	4（5%）	185	54	47	4.16
P14	4（1:1.5）	2（3%）	3（4%）	169	42	44	4.66
P15	4（1:1.5）	3（4%）	2（3%）	163	35	39	5.41
P16	4（1:1.5）	4（5%）	1（2%）	154	24	34	6.37

4. Single shaft deformation and failure characteristics of fly ash

The full stress-strain curves of the fly ash solidified filling material are shown in Figure 1 below. Through the proportioning of filling materials in the wdw-100E type microcomputer control electronic universal testing machine (size with a diameter of 50 x 100 mm) the backfill should be stress - strain curves, basically have the same rules, showing obvious nonlinear characteristics.

5. Conventional three axis deformation characteristics of fly ash

Generally speaking, the closed walls in the goaf by roof, floor and mining field rock interaction in triaxial state of stress. Therefore, the study of fly ash stabilized backfill in three to the stress state of deformation characteristics is very necessary. The 0.5MPa, 1.0MPa and 1.5MPa are used in the conventional three axis compression test of the electro-hydraulic servo static and dynamic static and dynamic three axis test machine. The test results are shown in Figure 1. Three axis compression shows that the specimen has similar deformation process under the condition of three axial compression. The deformation and failure of the specimen under stress are followed in 4 stages: elastic deformation stage, yield stage, plastic deformation stage and plastic failure stage.

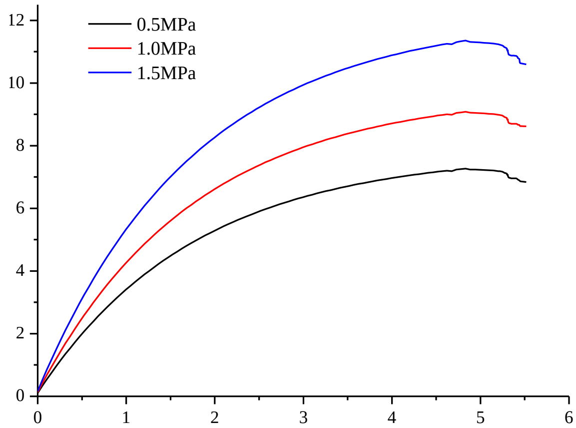

Fig. 1 stress-strain curves of solidified fly ash specimens under three axial compression

Elastic stage I: the stress-strain curve of the stage is basically a straight line, in the confining pressure and axial compression of the joint effect of the test piece in the pore space is gradually compressed density. The properties of the raw fracture in the specimen are basically unchanged, and the deformation can be recovered.

II the yield stage II: when the loading stress exceeds the limit of proportionality should be stress - strain curve is no longer a straight line, in yield phase test pieces in the consolidation of fly ash particles between the primary microcracks gradually expanded and deepened, constantly creating new microcrack. In the later stage of the stage, the growth rate of deformation is accelerated, and the plasticity of the specimen is further strengthened.

Plastic deformation stage III: after the yield stage is completed, the stress-strain curve changes relatively slowly, and the specimen is in the plastic deformation stage. The deformation of the specimen is accelerated, and the stress and deformation are not stable.

Fracture stage IV: plastic deformation stage is coming to an end, the stress-strain curve downward trend, showing strain hardening plastic failure mode. The stress value decreases with the increase of the pump oil pressure value, which indicates that the specimen has been completely destroyed.

Triaxial compression test of trace showed that damage fracture distribution depends on the test piece is not homogeneous weak point position. Therefore, the fracture is irregular. Test the characteristics of the deformation of the show the solidifying fly ash filling materials mechanics characteristics, namely consolidating filling material before reaching the yield point, with elastic supporting role; a yield point, played a certain pressure supporting role.

6. conclusion

(1) by orthogonal method to design the experimental scheme of water cement ratio, water glass, hydrated lime, three levels and four factors, the orthogonal method in 16 kinds of ratio of fly ash slurry were fluidity, initial and final setting time and material grout solidifying 28d compressive strength were tested, by using analysis of range and variance and ultimately determine the optimal ratio of solidifying fly ash filling materials: water cement ratio 1:1.5, 5% water glass, hydrated lime, 2%.

(2) showed that the uniaxial compression test of fly ash: the failure of specimens are divided into 3 types: the failure of conjugate slant shear failure, shear failure and tensile single bevel; before and after stress - strain curve stress in the peak are highly nonlinear, has good elastic deformation ability and filling material, plastic the plastic deformation capacity has the prominent characteristic and relatively poor; according to the uniaxial compression test of fly ash the variation law of stress and strain curve, the fly ash solidified material is divided into 5 stages: compaction stage, elastic stage, plastic stage (failure stage), strain softening stage and the residual deformation stage, the 5 stage shows that the solidified fly ash filling materials for underground sealing filling has certain bearing capacity and deformation resistance.

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