International Journal of Energy
ISSN: 2957-9473 | Vol. 3, No. 1, 2023

Experimental Study on the Proportioning of Grouting Materials for Fractured Roadways

Peihao Li, Pan Chi and Jinhai Gao

School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo, China

Abstract: For broken, low overall strength roadways, anchor cable and anchor mesh support are generally adopted. Sometimes, grouted anchor cable support is both an economical and safe support method. Therefore, the design of grouting materials and ratios plays a stewardship role. Through the proportioning experiments of cement slurry and water glass, a suitable proportioning scheme and the determination of various parameters were identified. According to the analysis of the test results, a slurry mixture of ordinary silicate cement with a water-cement ratio of 0.8 and water glass with a volume ratio of 1:0.5 is more suitable for the site grouting conditions.

Keywords: Fractured Roadway; Grouting Material; Roadway Support; Proportioning Design.

1. Introduction

At present, most of the coal mining methods in China are shaft mining, so the support of the roadway becomes an important part. Especially for the support of broken roadways, anchor injection technology is usually used for reinforcement, while applying grouting technology, grouting materials and suitable matching ratio become a key point, the grouting materials currently used are mainly chemical slurry and cement slurry, chemical slurry is expensive, only used for small amount of special local reinforcement. Cement slurry can be divided into two categories, one is ordinary single-liquid cement slurry and the other is cement-water glass slurry. Therefore, in this paper, through a series of indoor tests, the main study of cement and water glass different ratios, mixing ratio on the slurry performance of the law of the slurry must meet the performance requirements, and recommend the preferred ratio, for the broken rock grouting test and anchor injection support project to provide a certain scientific basis, for similar conditions of the support project design and construction is also very important reference and reference significance.

2. Test Raw Materials and Mix Design

2.1. Testing Raw Materials

The grouting materials currently used are chemical slurry and cement slurry two types, chemical slurry because it is expensive, combined with the project cost and practical application, selected P.O42.5 ordinary silicate cement and neutral sodium silicate, also known as water glass, produced by Hebi City Shuishan Bonding Materials Co Ltd, of which the physical and chemical indicators of water glass are shown in Table 1.

Table 1. Main physical and chemical properties of water glass

Appearance	Den-sity (g/cm^3)	Water insoluble matter content (%)	Sodium oxi-de content(%)	Mod-ulus (M)	Silicon diox-ide content(%)	Pom-erol
Translucent liquid	1.41	0.2	8.6	3.2	27.6	39

2.2. Mixing Ratio Design

Table 2. Mixing ratio design

Test number	Water-cement ratio	Cement slurry water glass volume ratio
1	0.8	1:0.5
2	0.8	1:0.75
3	0.8	1:1
4	1	1:0.5
5	1	1:0.75
6	1	1:1

When grouting a fractured coal body, the slurry needs to meet the requirements of good fluidity within a short period of time, short initial setting time and high early and medium-term strength of the consolidated body, for this reason, this test focuses on two performance indicators, namely the setting time and uniaxial compressive strength of the slurry. The factors affecting the performance of the slurry are many and complex, but under certain conditions such as cement and water glass, different water-cement ratios and the ratio of cement slurry to water glass are mainly considered, and the specific ratios are shown in Table 2.

3. Slurry Performance Indicators

3.1. Slurry Setting Time

The slurry setting time is the time elapsed between the mixing of cement slurry and water glass and the loss of liquidity of the slurry liquid and the formation of a solid mass of a certain strength. The setting time is one of the important parameters of the slurry performance and must be reasonably regulated for the injection slurry. If the setting time is too short, the slurry will lose its fluidity in the injection pipe before it is injected into the broken coal body, resulting in blocking of the pipe, which will also cause poor support effect; if the setting time is too long, the broken coal body will not be controlled effectively in time, especially in the back mining roadway, which will easily produce serious roofing

phenomenon.

The gel time is usually tested by the 'pouring cup method', where beakers are used to mix different cement slurries and water glasses, and the slurry is repeatedly poured in two beakers, and the time elapsed when the slurry is no longer flowing at a 45° tilt of the beaker is the gel time of the slurry. 3 samples are taken as a group and the average value is taken.

3.2. Uniaxial Compressive Strength

The compressive strength of cement-water-glass slurry nodules is high, especially the early strength is relatively high, and the strength growth rate is fast. The compressive strength is related to the cement slurry water-cement ratio, water-glass concentration, and cement to water-glass volume ratio. Separately, the above exclude the gel time is too long or too short of the remaining mix ratio and then compressive strength test.

Strength is one of the most important aspects of slurry properties. For slurry reinforcement of fractured coal rock, the slurry must not only meet the requirement of short setting time, but must also have high early and late strength to ensure the strength of the whole solid and the bond strength of the slurry mass to the anchor rod to achieve the designed anchorage force. In general, the early strength of the slurry is required to be 4-20Mpa, but the strength of the slurry needs to be determined taking into account the geological conditions of the site.

The uniaxial compressive test procedure is as follows:

1. Prepare slurries with different water-cement ratios in the laboratory and achieve the preparation of cement-water-glass slurries with different ratios by the addition of water-glass.

The slurry was prepared in the laboratory with different water-cement ratios.

2. The mould size was a cylindrical mould of 100mm in height and 50mm in diameter.

3. The slurry of different proportions is poured into the mould according to the designed test protocol.

4. Fill the moulds with different proportions of cement-water-glass slurry to produce cement-water-glass specimens.

5. Curing the specimens in the maintenance room.

6. Test the mechanical properties of the specimens and record them.

4. Analysis of Test Results

4.1. Freezing Time Test Results

The results of the cement slurry setting time data for different ratios were plotted into a correlation curve, as shown in Figures 1~3.

As can be seen from Figures 1~3, when the water-cement ratio is fixed, the setting time of the double slurry increases gradually as the volume ratio of cement slurry to water glass increases, and when the volume ratio of the double slurry is greater than 0.3, the rate of increase when setting increases significantly, Figure 1 when the volume ratio of the double slurry is 1, there is a reduction in setting time, and there may be experimental errors, but the overall trend shows an upward trend. When the cement slurry and water glass volume ratio is constant, with the increase of water-cement ratio, the overall decreasing trend, only when the double slurry volume ratio is small, the setting time is basically stable. In general, under this experimental condition, it shows that the more water glass is added, the slower the setting time is, the larger the water-cement ratio is, and when the water glass addition is small, the effect is not significant, and when the water glass addition is larger, the setting time becomes larger. On balance, the short setting time is not suitable for subsequent tests, and it was found during the experiments that when the water-cement ratio was 0.6, the consolidation rate was not high, so it was excluded. The remaining ones were selected for the mix design.

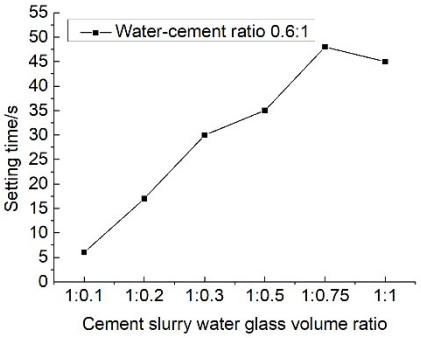


Figure 1. W:C 0.6:1

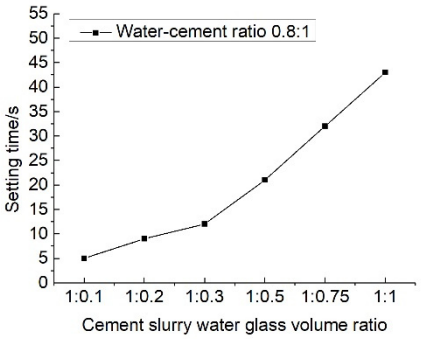


Figure 2. W:C 0.8:1

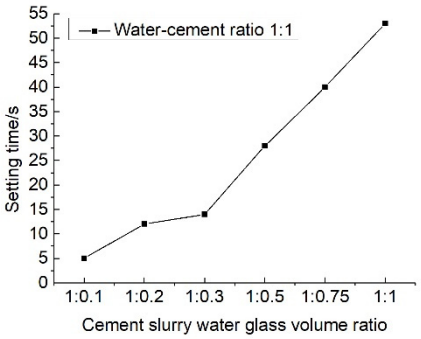


Figure 3. W:C 1:1

4.2. Uniaxial Compressive Strength Test Results

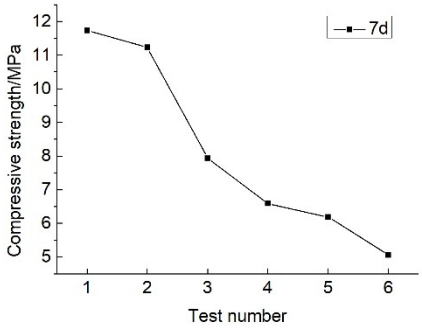


Figure 4. 7day uniaxial compressive strength

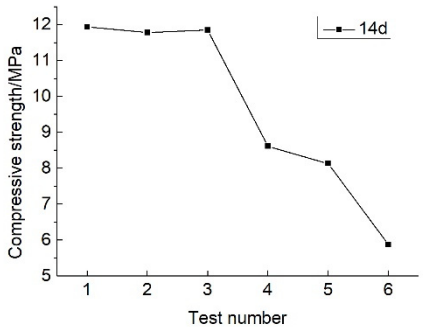


Figure 5. 14day uniaxial compressive strength

From Fig. 4~5, it can be seen that the early strength is higher when the ratio is water-cement ratio is 0.8 and volume ratio is 0.5, reaching 11.73Mpa, with the increase of water-cement ratio and water glass addition, the overall compressive strength is a decreasing trend, when the water-cement ratio is 1 and volume ratio is 1, the compressive strength is 5.6Mpa, with the increase of maintenance time, the growth of medium-term compressive strength is not much, basically at 5.87Mpa~11.94Mpa, thus it can be seen that the early strength has basically reached 95% of the final stage.

5. Conclusion

The setting time law of ordinary silicate cement and water glass is obtained, when the water-cement ratio is certain, with the increase of water glass admixture, the setting time increases, basically in about one minute, considering the economic cost and the actual situation of the project, the need to add retarder.

Cement water-glass solidification body strength is moderate, water-cement ratio of 0.8, water-glass admixture of 0.5, with good fluidity, and high early strength, up to 11.73Mpa, while the setting time of 21S, considering the actual engineering conditions, the need to add slow-setting agent, the time control in about 10 minutes, to ensure that the liquid injectability.

References

[1] Tong F, Yang J, Zheng C, et al. Research on the Comprehensive Evaluation of Grouting Quality Based on Fuzzy Rock Engineering System and Variable Fuzzy Set Theory[J]. International Journal of Fuzzy Systems, 2022,25(3).

[2] Wang C, Zhao W, Guo C, et al. Surface Free Energy Theory for Evaluating Moisture Damage in Expandable Polyurethane Grouting Materials[J]. Advanced Engineering Materials, 2022,24(11).

[3] Wang X, Cheng H, Yao Z, et al. Theoretical Research on Grouting in Deep Loose Layers Based on the Cylindrical Diffusion Model of Radial Tube Flow[J]. Geofluids, 2022,2022.

[4] Zhiyong H, Baiquan L, Yabin G, et al. Establishment and application of drilling sealing model in the spherical grouting mode based on the loosing-circle theory[J]. International Journal of Mining Science and Technology, 2012,22(6).

[5] Dang L W, Yue G. Empirical Formula of Chemical Grouting Pressure in Porous Media Based on Similarity Theory[J]. Applied Mechanics and Materials, 2011,1366(71-78).

[6] Wang H. Development of Theories and Methods on Water-Inrush Risk Evaluation and Grouting Reinforcement Technique for Lower Group Coal Seam Floor in Northern China Typed Coalfields[J]. American Journal of Science and Technology, 2016,3(5).

[7] H. S, G. G, L. H. Application of New Theories and Technology for Grouting of Dams and Foundations on Rock[J]. Geotechnical and geological engineering, 2012,30(3).

[8] Wang X, Cheng H, Yao Z, et al. Theoretical Research on Sand Penetration Grouting Based on Cylindrical Diffusion Model of Tortuous Tubes[J]. Water, 2022,14(7).

[9] Wang H, Dong L, Zhang Q, et al. Permeation grouting mechanism of viscous time-varying fluid considering diffusion path[J]. Frontiers in Earth Science, 2023.

[10] Kang H, Li W, Gao F, et al. Grouting theories and technologies for the reinforcement of fractured rocks surrounding deep roadways[J]. Deep Underground Science and Engineering, 2022,2(1).

[11] Qin N, Ye F, He B, et al. Model study on backfill grouting in shield tunnels based on fractal theory[J]. European Journal of Environmental and Civil Engineering, 2022,26(12).

[12] Huai F T. Analysis of Small Non-Sand Concrete Pile Grouting Pressure Based on Unified Strength Theory[J]. Applied Mechanics and Materials, 2012,1799(166-169).