Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2014, 6(11):645-652

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Experiment research on cemented backfill material with unclassified tailings

Yang Bao-gui*, Bao Tian-cai, Lu Hui, Liu Lu, Lu Zhi-jiang and Wang Fu-li

Faculty of Resources & Safety Engineering, China University of Mining & Technology, Beijing. Xueyuan Road, Ding 11, Haidian District Beijing, P. R. China

---

ABSTRACT

To solve the problem of reasonable ratio of cemented backfill material in unclassified tailings, the unclassified cement filling experiments, based on the two cement material which are ordinary portland cement and slag cement, were carried out. The matching laws based on different cement materials were summarized. Meanwhile, the orthogonal experiment and single experiment of different admixtures were also performed. The influence of different admixtures on strength of unclassified tailings cemented backfills was obtained. The study results show that it is unobvious cementation effect between the ordinary portland cement and the slag cement. With addition increasing, the cementation effect of ordinary portland cement is better than that of slag cement apparently. The amount of slag cement addition is suggested below 3%. Comparing the orthogonal experiment with single additive experiment, the strength is improved because of the additive Na_2CO_3 *and* $KAl(SO_4)_2 \bullet 12H_2O$. *They aren't obvious effect for strength, such as* Na_2SiO_3, Na_2SO_4 *and* $CaSO_4$.

Key words: unclassified tailings; cemented filling; admixture; orthogonal experiment

---

INTRODUCTION

The cemented unclassified tailings backfill (CUTB) mixed by cement， water and unclassified tailings. In the technology process of CUTB, unclassified tailings provided by mine concentrator are used as filling aggregate, ordinary portland cement or slag cement are mixed as cemented materials, water and other additives are added to prepare high concentrations of filling slurry, which are transported by artesian pipe or pumping to the filling site. The filling slurry has the characteristics of without segregation during transport, homogeneous structure fluid, easy flow, less wear and tear on the pipes, and no dehydration, so as to improve the working environment [1-3]. The backfill have some characteristics, such as good entirety, small shrinkage, smooth surface, rare segregation and stratification, which can contribute to form a stable structure so as to improve the state of wall rock stress and effectively control the movement and deformation of the surrounding rock. The backfill plays an important role in wall rock control and ground pressure activity management of stope in the deep mining [4-5]. The CUTB, overcoming the disadvantages of complex process, low utilization efficiency of backfilling system and insufficient supply of tailings, made full use of various size tailings to produce high concentration slurry [6]. Compared with other backfill technology, CUTB can reduce the dosage of cement to decrease the mining cost and realize recycling mining waste, such as tailings to protect the ecological environment. What's more, the method also effectively control surface subsidence caused by mining, so as to solve the "three-unders" coal mining and improve coal recovery rate [7].

In the practical applications of CUTB, the factors, such as the slurry concentration, binders and admixtures, have certain impact on the strength of CUTB. Many scholars researched on the effect of slurry concentration and cemented materials on the performance of backfill [8-15]. Based on previous research results, the orthogonal tests and single contrast tests, with ordinary portland cement and slag cement as cemented materials by adding different kinds of admixture, were carried out to study the impact of different admixtures on the strength of cemented tailings backfill. These results will provide a certain theoretical basis and a good reference value for practical application.

2 Cemented materials selection and matching tests

2.1 Experimental design

CUTB, provided by mine concentrator, 425 ordinary portland cement and slag cement, were used in the experiment. The slurry with a concentration of 80% were evenly prepared with tailings, 425 ordinary portland cement (or slag cement) and water at room temperature, then poured into the size of the 7.07 cm × 7.07 cm × 7.07 cm standard test molds to make up a number of criteria test modules. Uniaxial compression strength tests were carried out in pressure testing machine after stripping the 3, 7, 28 days in curing room.

2.2 Results analysis

The results of contrasting tests with ordinary portland cement and slag cement were carried out to study on the impacts of different dosages of cement on the strength of CUTB, as shown in Table 1 and 2. The results indicate that the more dosage of cemented material and the longer the service life, the stronger the compressive strength. Under the same conditions, the strength of CUTB with slag cement were more than that of ordinary portland cement, which indicated that the effect of slag cement for cemented tailings backfill better than ordinary portland cement. The character of hydration activity was showed that slag cement contained slag. Thus, it is of great significance to use slag cement as substitution for a certain dosage of ordinary portland cement in engineering.

Table 1 Effect of ordinary portland cement on the performance backfill

Dosage of ordinary portland cement	Compressive strength of backfill at different ages		
	3d	7d	28d
1%	0.073	0.088	0.097
2%	0.159	0.225	0.298
3%	0.35	0.48	0.712
5%	0.49	0.90	1.232

Table 2 Effect of slag cement on the backfill performance

Dosage of slag cement	Compressive strength of backfill at different ages		
	3d	7d	28d
1%	0.076	0.096	0.113
2%	0.173	0.279	0.382
3%	0.38	0.54	0.910
5%	0.54	0.80	1.296

In terms of compressive strength of cemented tailings backfill at the same age, it didn't appear to be much difference between ordinary portland cement and slag cement under the condition of low dosage, as shown in Table 1 and 2. For example, the strength of CUTB, added ordinary portland cement and slag cement with the same dosage of 1% after curing to 28 days, were respectively 0.097 MPa and 0.113 MPa. However, with the increase of dosage of cemented materials, the cemented effect of slag cement is superior to ordinary portland cement. As shown in the tables 1 and 2, with the same dosage of 3% after stripping and curing to 28 days, the strength of slag CUTB was 0.910 MPa, it was obviously better than that of ordinary portland cement 0.712 MPa.. With the dosage of cemented material increased to 5%, the strength of CUTB , added ordinary portland cement and slag cement, increased to 1.296 MPa and 1.232 MPa under the condition of stripping and curing to 28 days. The results indicate the superiority of slag cement weakened. In conclusion, the advisable dosage rate should be controlled at about 3% adding slag cement.

Under the condition of same age, the strength of CUTB added low 3% slag cement improved faster than that of ordinary portland cement. Oppositely, once the dosage of cemented materials added more than 3%, the strength of CUTB improved slower than that of ordinary portland cement. As can be seen from the tables 1 and 2, after curing for 7 days, the strength of ordinary portland CUTB and slag CUTB respectively increased 188% and 156% with the dosage from 1% to 2%. As shown in table 1 and 2, the strength of CUTB added slag cement was 0.80 MPa, less than that of ordinary portland cement 0.90 MPa when the dosage of cemented material increased to 5%. Meanwhile, the results show that there was much difference when the dosage of cemented material increased from 2% to 3%. For example, the strengths of CUTB were from 0.382 MPa and 0.910 MPa as addition of slag cement from 2% and 3%. In practical applications, it is advisable to apply the optimal cement ratio according to the specific circumstances of the mine meeting different requirements and optimizing the economic cost.

3 Additive effects on backfill performance

3.1 Additive effects on strength of backfill

Based on the tests, these research analyses on the impact of additive effects on the strength of backfill were carried out. The results are shown in Table 3. As can be seen from the table 3, there was somewhat influence on the early strength of CUTB added additives, the strengths were up from about 0.37 MPa to 0.44 MPa after 3 days. It isn't effect tended to be negligible.

Table 3 Effect of admixture on the CUTB performance

Dosage of slag cement		Compressive strength of backfill at different ages		
		3d	7d	28d
3 %	Added addmixture	0.37	0.55	0.914
		0.38	0.54	0.910
	Without addmixture	0.44	0.56	0.922
		0.448	0.546	0.931

3.2 Orthogonal experiments on admixture matching and effect

For CUTB in mine, the demands of shortening the cementation time and increasing early strength were made. Therefore, In the experiment, the admixtures were selected combining with the field application, such as Na_2SiO_3, Na_2CO_3, $KAl(SO_4)_2 \bullet 12H_2O$, Na_2SO_4 and $CaSO_4$. Experiments were carried out upon 5 factors and 4 levels experimental design to test the strength of CUTB at different ages. The value of various factors and the orthogonal experiment design were presented as Table 4 and 5. The experimental results are shown as Figure 1 to 5.

Table 4 Value of various factors and levels

Factors / Levels	A Na_2SiO_3	B Na_2CO_3	C $KAl(SO_4)_2$•$12H_2O$	D Na_2SO_4	E $CaSO_4$
1	0	0	0	0	0
2	0.05	0.05	0.05	0.05	0.5
3	0.1	0.1	0.1	0.1	1
4	0.2	0.2	0.2	0.2	2

Table 5 Orthogonal experiment design

List numbers / Test numbers	A Na_2SiO_3	B Na_2CO_3	C $KAl(SO_4)_2$•$12H_2O$	D Na_2SO_4	E $CaSO_4$
HA-1	0	0	0	0	0
HA-2	0	0.5	0.5	0.5	5
HA-3	0	1	1	1	10
HA-4	0	2	2	2	20
HA-5	0.5	0	0.5	1	20
HA-6	0.5	0.5	0	2	10
HA-7	0.5	1	2	0	5
HA-8	0.5	2	1	0.5	0
HA-9	1	0	1	2	5
HA-10	1	0.5	2	1	0
HA-11	1	1	0	0.5	20
HA-12	1	2	0.5	0	10
HA-13	2	0	2	0.5	10
HA-14	2	0.5	1	0	20
HA-15	2	1	0.5	2	0
HA-16	2	2	0	1	5

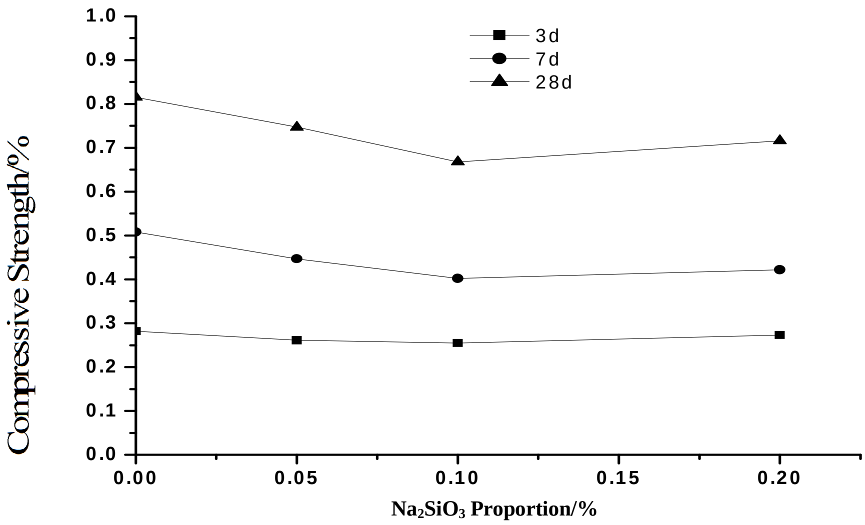

Figure 1 Additive effect of Na_2SiO_3 on the backfill strength

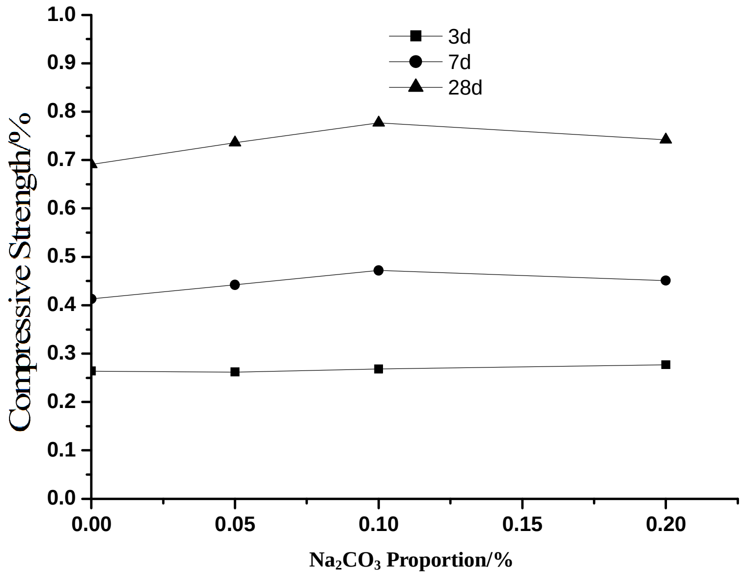

Figure 2 Additive effect of Na_2CO_3 on the backfill strength

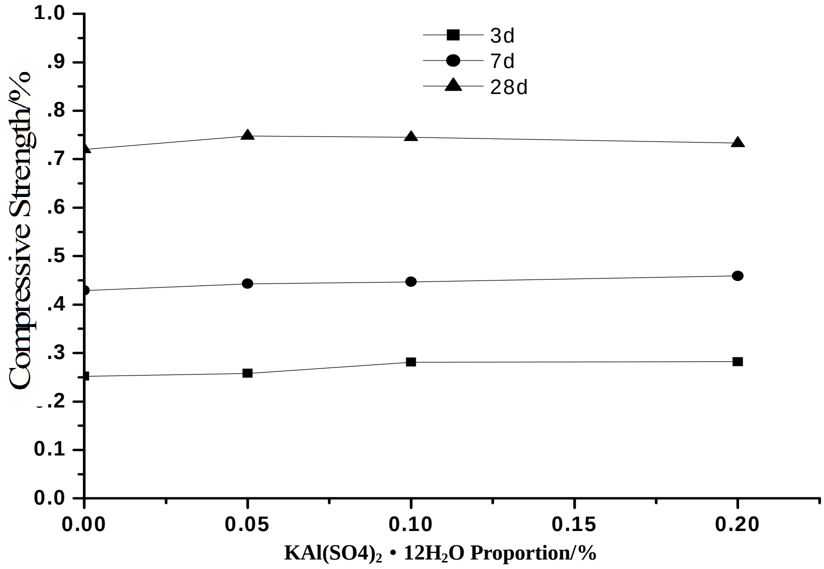

Figure 3 Additive effect of $KAl(SO4)_2 \cdot 12H_2O$ on the backfill strength

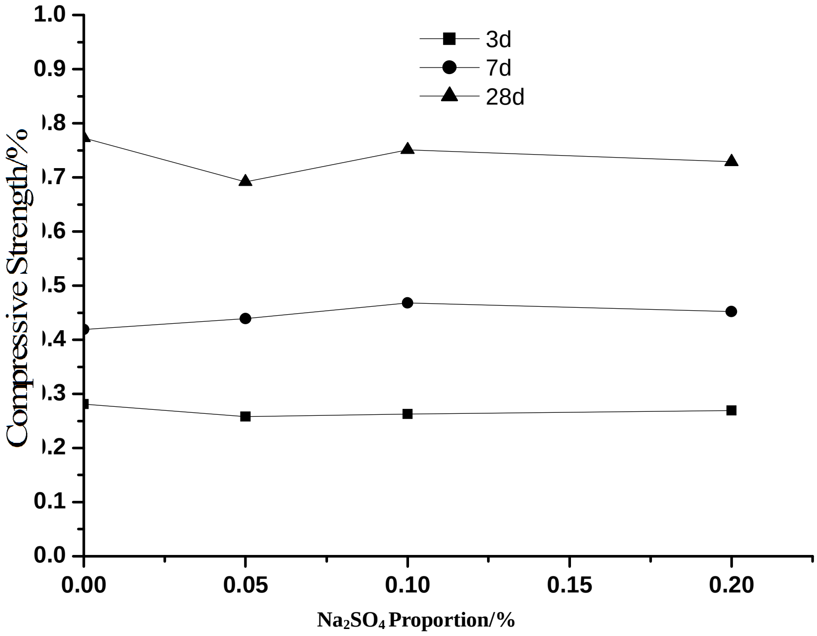

Figure 4 Additive effect of Na_2SO_4 on the backfill strength

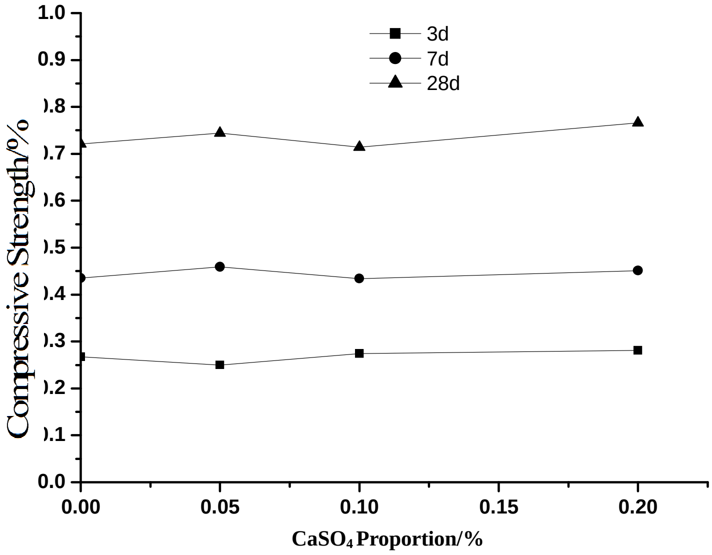

Figure 5 Additive effect of $CaSO_4$ on the backfill strength

(1) As is shown in Figure 1, the strength of slag CUTB presented a downward trend with the dosage of Na_2SiO_3 below 0.1%, but the trend reversely turn to rise gradually once the dosage exceed 0.1%. What is noteworthy is that the strength of slag CUTB with 0.2% addition of Na_2SiO_3 was lower than the without addition. Theoretically, Na_2SiO_3 , an alkaline activator , can stimulate the hydration activity of slag so as to improve the strength of slag CUTB. However, the experimental results were contrary to the expectation, the reasons may be the chemical reaction of Na_2SiO_3 in the slurry was smothered due to fine grained tailings.

(2) As is shown in Figure 2, the strength of slag CUTB can be improved after curing 3 days. when the addition of Na_2CO_3 below 0.1%, the strength of slag CUTB was improved in terms of 7、28 days. However, the strength of slag CUTB turn to downward when the addition of Na_2CO_3 surpass 0.1%. Thus, the optimal dosage of Na_2CO_3 may be at 0.1%.

(3) As is shown in Figure 3, the addition of $KAl(SO_4)_2 \bullet 12H_2O$ can improve the strength of slag CUTB in views of curing after 3,7 and 28 days. In other words, the $KAl(SO_4)_2 \bullet 12H_2O$ can strengthen slag CUTB not only at early days but also at long-terms. However, it is obvious that the effect grew slower and slower when the addition surpassed 1%. Especially, the strength was decreased tested at 28 days. Therefore, the optimal dosage of $KAl(SO_4)_2 \bullet 12H_2O$ may be at 0.1%.

(4) As is shown in Figure 4, the addition of Na_2SO_4 can improve the strength of slag CUTB at 7 days, but there was decrease in that of 3 days and 28 days. In terms of 3, 28 days, the strength of slag CUTB with 0.2% addition of Na_2SO_4 was lower than that the without addition. Therefore, it only at 7 days that the addition of Na_2SO_4 can somewhat strengthen the slag cemented tailings.

(5) As is shown in Figure 5, the addition of $CaSO_4$ had a little effect on the strength of slag CUTB, and both the

growth rate and amplification were unremarkable.

3.3 Single additive experiments

The Single additive experiments were conducted to test the strength of slag CUTB with different proportion of additives. The CUTB were prepared with 3% dosage of slag cement and different dosage of additives, such as Na_2CO_3, Na_2SO_4, $KAl(SO_4)_2 \bullet 12H_2O$, gypsum, calcined gypsum, and other filling materials. The results are shown as Table 6.

Table 6 Single additive experiments on backfill strength

Admixtures	Dosage %	Compressive strength /Mpa			Test numbers
		3d	7d	28d	
Na_2CO_3	0.1	0.350	0.504	0.653	HC-1
	0.2	0.339	0.503	0.586	HC-2
	0.3	0.405	0.489	0.691	HC-3
	0.4	0.368	0.576	0.900	HC-4
Na_2SO_4	0.1	0.481	0.500	0.907	HD-1
	0.2	0.448	0.546	0.931	HD-2
	0.3	0.455	0.454	0.896	HD-3
	0.4	0.385	0.508	0.876	HD-4
$KAl(SO_4)_2 \bullet 12H_2O$	0.1	0.401	0.525	0.764	HE-1
	0.2	0.397	0.540	0.705	HE-2
	0.3	0.364	0.564	0.756	HE-3
	0.4	0.344	0.499	0.762	HE-4
calcined gypsum	1	0.385	0.441	0.702	HF-1
	3	0.348	0.412	0.806	HF-2
	5	0.328	0.417	0.777	HF-3
	7	0.340	0.502	0.534	HF-4
gypsum	1	0.353	0.400	0.737	HG-1
	3	0.345	0.422	0.818	HG-2
	5	0.330	0.525	0.817	HG-3
	7	0.332	0.499	0.779	HG-4

As was shown in Table 6, the results shows that the addition of Na_2CO_3 had little influence on the strength of backfill in early-day, while the improvement were remarkable in later-day. The addition of $KAl(SO_4)_2 \bullet 12H_2O$ and gypsum had somewhat increase in the strength of backfill at 7 days, while the effect was little on that of 3, 28 days. Other additive, such as Na_2SO_4 and calcined gypsum had hardly even negative effect on the improvement of backfill strength.

CONCLUSION

Based on laboratory tests, the following conclusions can be made:

(1) The effect of slag cement for CUTB was faint with low dosage. But with the dosage increased, the slag cement was better than ordinary portland cement under the same condition. The hydration activity of slag cement containing slag may make a difference. Thus, it is of great significance to use slag cement as substitution for a certain dosage of ordinary portland cement in practice.

(2) Under the condition of same age, the strength of CUTB added slag cement rose faster than that of ordinary portland cement with the increase but no more than 3% dosage of cemented materials. Oppositely, once the dosage of cemented materials increased more than 3%, the strength of cemented tailings backfill added slag cement rose slower than that of ordinary portland cement. Thus, the dosage of slag cement should be controlled below 3%.

(3) There was much difference when the dosage of cemented materials increased from 2% to 3%. In practical applications, it is advisable to apply the optimal cement ratio according to the specific circumstances of the mine to meet different requirements and optimize the economic cost. In case the demand for strength prior to economical cost, it is wise to adopt 3% dosage of cemented material. Correspondingly, if the consideration for economical cost is prior to strength, the 2% dosage of cemented material should be applied to save cost.

(4) The addition of Na_2CO_3 and $KAl(SO_4)_2 \bullet 12H_2O$ had somewhat influence on the strength of backfill, while the improvement was remarkable with a certain range of concentration. Other additive, such as Na_2SiO_3, Na_2SO_4,

$CaSO_4$,gypsum and the calcined gypsum had hardly even negative effect on the improvement of backfill strength.

Acknowledgments

We thank the financial support from the Key Technology P&D Program supporting project of the National ‘Eleventh Five-Year-Plan’ of China (No. 2009BAB48B02), the Specialized Research Fund for the Doctoral Program of Higher Education (No. 20120023120008), the Fundamental Research Funds for the Central Universities (No.2011QZ01), National Students' Innovation and Entrepreneurship Training Program (No.201211413013, Y20131110, 201411413069).

REFERENCES

[1] Brackebusch F W, *International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts.* , **1995**, 32(3).
[2] Knissel W, *Erzmetall. Mining in terms of waste disposal in Germany*. , **1999**, 52(12), 666-672.
[3] HE Zhe-xiang; XIE Kai-wei; ZHOU Ai-min, *The Chinese Journal of Nonferrous Metals. Research and practice of total tailings backfilling.* , **1998**, 8(4), 739−744.
[4] Belem T; Benzaazoua M; Bussière B, *Proc. of 53rd Candadian Geotechnical Conference, Montreal. Mechanical behaviour of cemented paste backfill*. , **2000**, 373-380.
[5] Belem T; Benzaazoua M; *Geotechnical and Geological Engineering. Design and application of underground mine paste backfill technology*., **2008**, 26(2), 147-174.
[6] Kesimal A; Ercikdi B; Yilmaz E, *Minerals Engineering*. **2003**, 16(10), 1009-1011.
[7] Bryan R; Simms P; Verburg R, *Minerals Engineering*. **2010**, 23(14), 1101-1112.
[8] Yilmaz E; Belem T; Bussière B, et al, *Proceedings of the 3rd International Symposium on Mines and the Environment, Rouyn-Noranda, Quebec, November. Evaluation of strength, microstructure and consolidation properties of cemented paste backfill using new laboratory equipment*., **2008**, 2-5.
[9] Yilmaz E; Kesimal A; Ercikdi B, *Turkish J. An. Earth Sci. The factors affecting strength and stability of paste backfill*., **2003**, 28, 155-169.
[10] Kesimal A; Yilmaz E; Ercikdi B, *Cement and concrete research*. **2004**, 34(10), 1817-1822.
[11] Kesimal A; Yilmaz E; Ercikdi B, et al, *Materials Letters*. **2005**, 59(28), 3703-3709.
[12] Fall M; Benzaazoua M; Ouellet S, *Minerals Engineering*. **2005**, 18(1), 41-44.
[13]Yilmaz E; Kesimal A; Ercikdi B, *Proceedings of the 10th International Conference on Tailings and Mine Waste, Balkema, Swets and Zeitlinger, Lisse12–15 October, Colorado, USA. Strength properties in varying cement dosages for paste backfill samples*., **2003**, 109-114.
[14]Sheorey P R; Das M N; Barat D, et al, *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts*. **1987**, 24(6), 347-355.
[15] Yilmaz E; Belem T; Benzaazoua M, et al, *Mineral Resources Engineering*. **2007**, 12(2), 129-144.