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MINERALOGY, PETROGRAPHY AND MANUFACTURING OF GOOD QUALITY BLACKBOARD CHALK

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معادن وبتروجرافية وتصنيع نوعيات جيدة من طباشير الكتابة

جامعة قطر – قسم الجيولوجيا ـ ص . ب ٢٧١٣ ـ الدوحة ـ قطر

ملخص

تنتج معظم الدول العربية نوعيات رديئة من طباشير الكتابة في حين يتم استيراد كميات كبيرة من الطباشير الجيد والصحي من أوروبا والصين وأمريكا . أن أهم المواد الخام اللازمة لصناعة الطباشير والتي تشمل الحجر الجيري والطباشيري والجبس أو الانهيدريت متوفرة بكثرة في الدول العربية خاصة في صخور العصر الثلاثي . لقد تم دراسة العوامل المؤثرة على صناعة وجودة الطباشير وتبين أن نسبة الماء والمعادن الأخرى مثل الكالسيت والجبس والمواد اللاحمة وكذلك حجم الحبيبات تلعب دوراً أساسياً في صناعة الطباشير من النوعية الجيدة.

Key words: Blackboard chalk, mineralogy, chemistry, manufacturing.

ABSTRACT

Most of the Arabian countries produce bad quality and dusty blackboard chalk. Good quality and dustless blackboard chalk are usually imported from Europe, China, Taiwan and the United States of America. The essential raw materials for the production of blackboard chalk include chalk variety of limestone and gypsum or anhydrite. These materials are available in large quantities, especially in the Tertiary sediments in most of the Arabian countries. Investigations on the factors which affect chalk production indicate that the amount of water and the percentages of calcium carbonate, gypsum and binders as well as the grain size of the different components are the controlling factors in the production of blackboard chalk.

INTRODUCTION

Good quality and dustless blackboard chalks are usually imported from Europe, China, Taiwan or the United States of America. According to the American National Standards for Chalk (1, 2), a blackboard chalk shall not be toxic or injurious to the human body as a result of any foreseeable handling or use, including ingestion of a large single dose. Chalk shall not contain asbestos or any substance that can cause respiratory tract irritation or lung damage after inhalation of blackboard chalk dust. The calcium carbonate and calcium sulphate content shall be determined in accordance with the applicable provisions of ASTM C25-81. The production of blackboard chalk includes searching for good quality raw materials, screening of raw materials, mixing with additives as binders then molding and drying. The essential raw materials which include limestone (chalk varieties), and gypsum or anhydrite are available in Qatar and the Gulf Region in large quantities especially in the Tertiary sediments (3-7).

The main purpose of this research is to study the mineralogy, petrography and physical properties of local and imported blackboard chalk and their relation to practical problems that arise in the manufacture of blackboard chalk. The following points will be discussed.

1. The constituents of blackboard chalks and the nature and properties of the compounds they contain.

2. The chemistry and changes which the raw materials undergo in the course of blackboard chalk manufacture and the influence of changes in composition and other factors on the properties of the product.

3. Analysis, manufacturing, testing and comparison of imported and local blackboard chalks.

Mineralogy of chalk

Several blackboard chalk samples manufactured in the United Arab Emirates, Jordan, Korea, China, Holland, England, France, Japan and the United States of America have been collected and analysed for their mineralogy and trace element composition. The mineral composition has been determined by X-ray diffraction. The texture has been determined by scanning electron microscope. The results of X-ray diffraction are given in Table 1. Chalk manufactured in Jordan, United Arab Emirates, Japan and China consists mainly of gypsum. Most of these blackboard chalks break easily and write badly on the blackboard, which is in contrast to chalk made from a mixture of calcite and gypsum. Such a blackboard chalk is manufactured in Holland, France, U.S.A. and England. Scanning electron microscopy of the different chalk samples are given in Figures 1-12. The blackboard chalk from Jordan is monomineralic and consists of fibrous crystals of gypsum (Fig. 1). The Korean blackboard chalk consists of very fine-grained micritic calcite (Fig. 2). The blackboard chalk from the United Arab Emirates consists of non homogeneous and finely crystalline gypsum and anhydrite with traces of portlandite (Fig. 3). The Japanese blackboard chalk consists of well crystalline fibrous and platy gypsum (Fig. 4). The Chinese blackboard chalk shows similar composition and texture to the blackboard chalk from the U.A.E. It consists of fibrous and prismatic crystals of gypsum and anhydrite (Fig. 5). Another Chinese variety shows non-homogeneous crystals (Fig. 6). Similarly also the blackboard chalk from Taiwan (Fig. 7). It consists of non-homogeneous platy crystals of gypsum and traces of fine-grained calcite. The French blackboard chalk consists mainly of fine-grained calcite and platy gypsum crystals (Figs. 8, 9). The blackboard chalk from Holland is composed of very fine-grained calcite and few fine-grained gypsum (Fig. 10). The blackboard chalk from England and from the United States of America consists of equigranular rhombic crystals of calcite with monoclinic crystals of gypsum and platy crystals of kaolinite (Figs. 11, 12).

Fig. 1. Scanning electron micrograph of chalk from Jordan showing fibrous crystals of gypsum

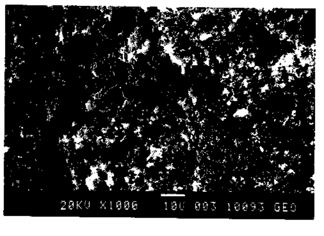

Fig. 2. Scanning electron micrograph of chalk from Korea showing fine-grained calcite and anhydrite

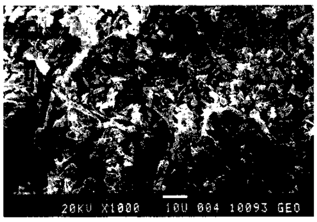

Fig. 3. Scanning electron micrograph of chalk from U.A.E. showing non-homogenous finely crystalline gypsum and portlandite

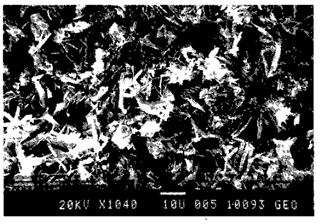

Fig. 4. Scanning electron micrograph of chalk from Japan showing fibrous and platy crystals of gypsum

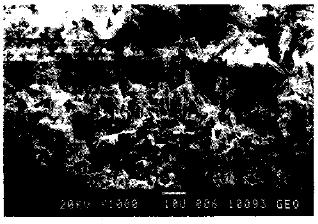

Fig. 5. Scanning electron micrograph of chalk from China showing fine-grained crystals of anhydrite

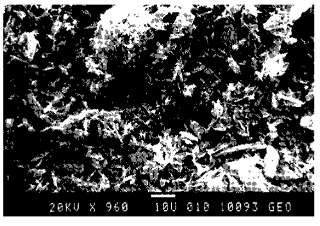

Fig. 6. Scanning electron micrograph of chalk from China showing non-homogenous crystals of gypsum

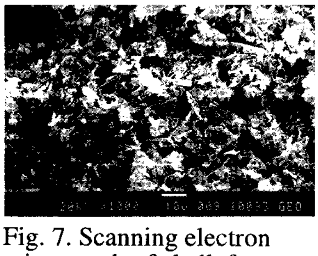

Fig. 7. Scanning electron micrograph of chalk from Taiwan showing platy crystals of gypsum

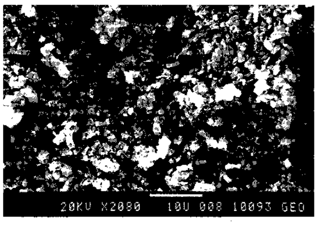

Fig. 8. Scanning electron micrograph of chalk from France shwoing fine-grained crystals of calcite

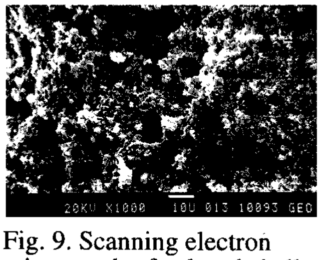

Fig. 9. Scanning electron micrograph of colored chalk from France showing fine-grained crystals of calcite and platy gypsum

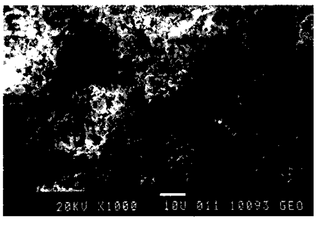

Fig. 10. Scanning electron micrograph of chalk from Holland showing fine-grained crystals of calcite

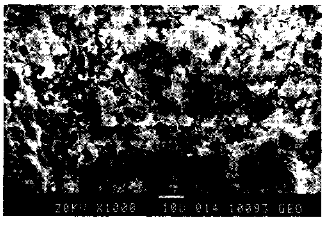

Fig. 11. Scanning electron micrograph of chalk from England showing rhombic crystals of calcite, and platy gypsum and kaolinite

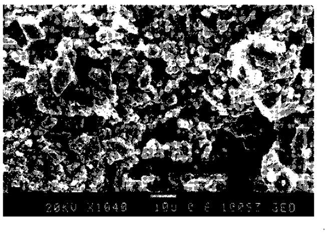

Fig. 12. Scanning electron micrograph of chalk from U.S.A. showing rhombic crystals of calcite and platy kaolinite

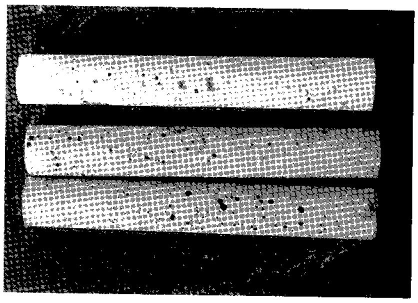

Fig. 13. Highly porous chalk from China

The breaking strength of the imported and local blackboard chalks is given in Table 2. The white Chinese and Jordan chalks show the lowest values. The Chinese chalk is very weak and highly porous (Fig. 13).

Chemical analysis of trace elements

(Table 3) indicates that most of the investigated blackboard chalk samples contain normal and non-hazardous amounts of trace elements with the exception of blackboard chalk from Korea which contains high amounts of Cu, Cr and Mn.

Manufacturing of blackboard chalk

The preparation of blackboard chalk included crushing and grinding of raw materials, screening of raw materials, mixing, molding, drying, and testing of product. Different types of good quality limestone ($CaCO3$, more than 95%) were collected and analysed for their carbonate content. Samples which show $CaCO3$ content of more than 95% have been chosen for crushing and grinding to fine powder. Screening of the carbonate powder was carried out using multi-sieve shaker (0.25, 0.15, 0.09, 0.063, 0.45 mm and pan). Screening was carried out in order to have uniform particles to measure the particle size for each sample. The main variables affecting chalk manufacturing are the following:

1. Percentage of $CaCO3$
2. Percentage of $CaSO4.2H2O$
3. Percentage of additives: CMC (carboxy methyl cellulose), PVA (poly vinyl alcohol), starch, ZnO, kaolinite, colored pigments.
5. Grain size

Starch, CMS or PVA and gypsum were used as binders. ZnO was used to give dustless property. Starch, CMC and PVA are well known polymers which can be used as thickner and water binder. CMC and PVA are white to cream-colored molding powder, usually used as binder for cosmetic preparations. CMC is an acid ether derivative of cellulose used as a stabilizer and emulsifier. It is negatively charged resign used in ion-exchange chromatography, also known as cellulose gum. CMC and PVA are non toxic. In blackboard chalk manufacturing either CMC or PVA is used. Kaolinite was used instead of starch and CMC in some experiments.

Fig. 14 shows the apparatus prepared for the manufacturing of chalk in this study. The following experiments have been carried out:

Experiment 1:

Constant weight percentages of limestone, starch, gypsum, CMC and ZnO were chosen first as fixed variables.

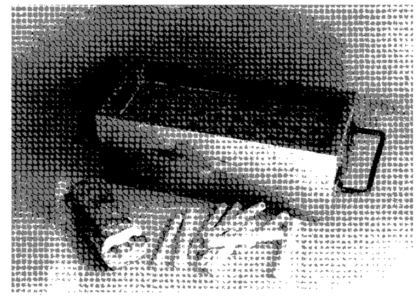

Fig. 14. Molding apparatus prepared for the manufacturing of chalk

Water was chosen first as fixed variables. Water was chosen as the only variable. Different volumes of water, were added in the following steps:

1. Water was added to the starch and CMC first, mixed together until a viscous solution was obtained.
2. $CaCO3$ and gypsum were then added
3. Mixing then molding and pressing to shape then drying.

Experiment 2:

Constant volume of water (100 cm) and constant weights of starch, gypsum and ZnO were chosen first as fixed variables. Different amounts of limestone, were added in the following steps:

1. Water is added to starch, ZnO and gypsum and mixed together until a viscous solution was obtained.
2. Limestone powder is added.
3. The samples were pressed, molded and dried in oven at 100°C.

Experiment 3:

Following the same procedure in experiments 1 and 2, the weight percentages of other components were determined by varying their percentages and fixing the others (experiments 4 to 7). The weight % of additives (water, starch, gypsum) were changed and other parameters ($CaCO3$) were fixed as shown in Tables 6 to 10.

The quality of produced blackboard chalk had been tested by writing on a blackboard. The results are shown in Tables 4 to 10. The best results as shown from the different experiments are as follows:

Grade 1 chalk (Figs. 15, 16): consists of either: 95% $CaCO3$, 1% gypsum, 2% CMC, 1% starch, 1% ZnO, 100% $H2O$ or 50% $CaCO3$, 25% gypsum, 15% kaolinite, 4% CMC, 4% starch, 2% ZnO.

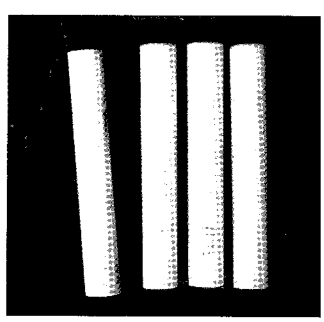

Fig. 15. Manufactured chalk of grade 1

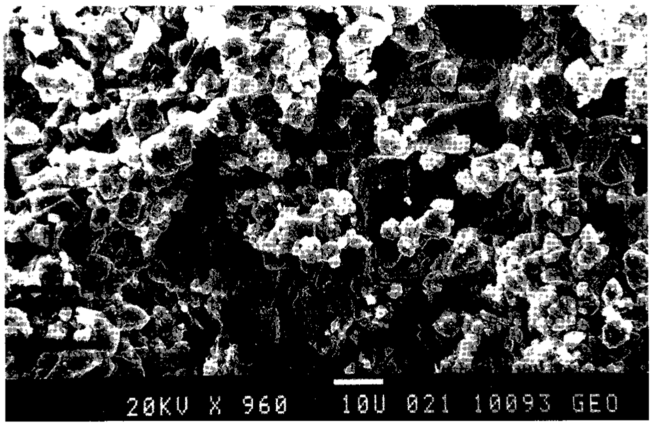

Fig. 16. Scanning electron micrograph of grade 1 chalk prepared in this study showing rhombic calcite, platy gypsum and kaolinite crystals

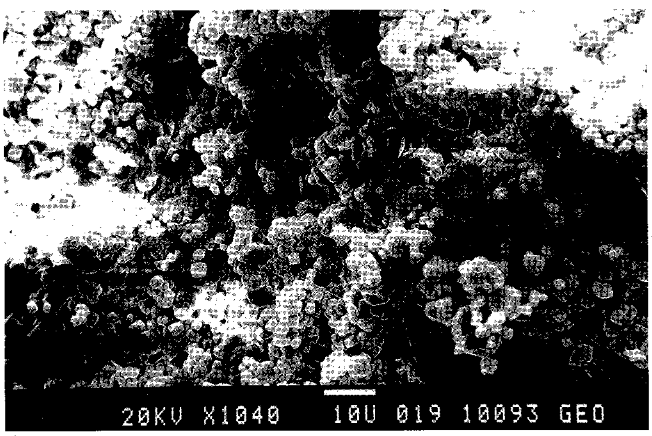

Fig. 18. Scanning electron micrograph of grade 2 chalk prepared in this study showing rhombic calcite and platy gypsum

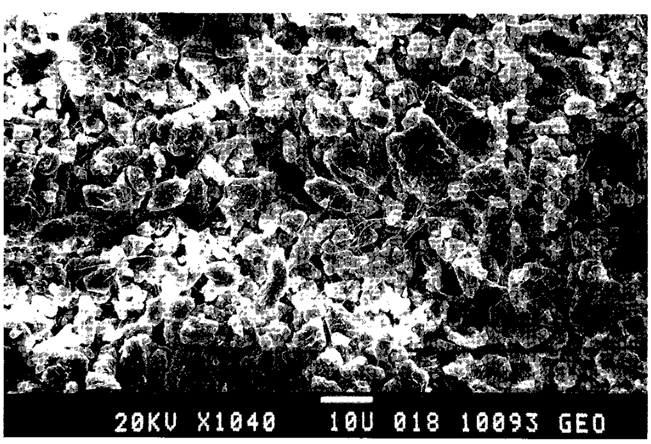

Fig. 20. Scanning electron micrograph of grade 3 chalk prepared in this study showing platy gypsum

Grade 2 chalk (Figs. 17, 18): consists of 86% CaCO3, 6% CMC, 6% starch, 2% ZnO and 100% water.

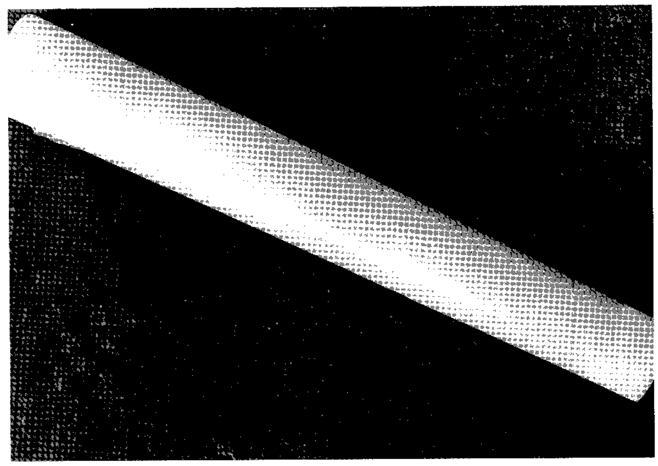

Fig. 17. Manufactured chalk of grade 2

Grade 3 chalk (Figs. 19, 20): consists of 92% gypsum, 1% CaCO3, 3% CMC, 3% starch, 1% ZnO and 100% water.

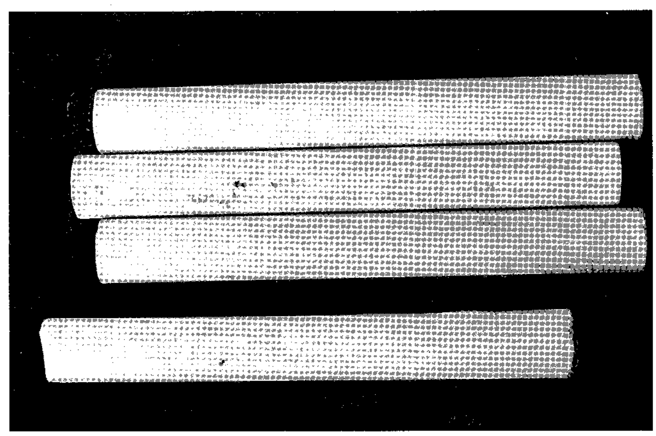

Fig. 19. Manufactured chalk of grade 3

The best types are those with raw material grain size of less than 0.063 mm (Table 10). Figure 21 shows texture of blackboard chalk made in this study in comparison to imported chalk.

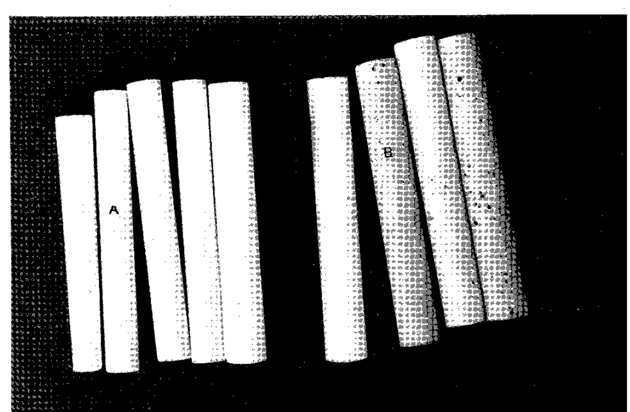

Fig. 21. Texture of chalk made in this study (A) in comparison to imported chalk (B)

Table 1
Mineralogy of imported and local chalks as determined by XRD

	Type of chalk	Mineralogy Major	Minor	Trace	Quality
1.	Jordan	Gypsum	–	Anhydrite	bad writing, dusty, breaks easily
2.	Korea	Calcite	–	Anhydrite	bad writing, dusty
3.	U.A.E., Majed	Gypsum	–	Anhydrite	bad writing, breaks easily
4.	Japan	Gypsum	–	Calcite	moderate quality
5.	Colored chalk (China, Elephant)	Gypsum	–	Calcite	bad writing, dusty
6.	White chalk (China)	Gypsum	–	Anhydrite	bad writing, dusty
7.	Taiwan	Gypsum	–	Calcite, Quartz	bad writing, dusty
8.	Colored chalk (France)	Calcite	Gypsum	–	good writing, not dusty
9.	White chalk (France)	Calcite	Gypsum	Quartz	good writing, not dusty
10.	Holland	Calcite	–	Gypsum	good writing, no dust
11.	England	Calcite	Gypsum Kaolinite	–	good writing, no dust
12.	U.S.A.	Calcite	Gypsum, Kaolinite	–	good writing, no dust
13.	President study	Calcite	Gypsum, Kaolinite	ZnO	good writing, no dust
14.	Present study (Grade 1)	Calcite	CMC, Starch	ZnO	good writing
15.	Present study (Grade 2)	Gypsum	CMC, Starch	ZnO	good writing, no dust

Table 2
Breaking strength of imported and local chalks

Country	Breaking strength Kg/Cm2
Jordan	24.8
Korea	37.4
U.A.E.	26.4
Japan	49.6
China, yellow	27.2
China, white	19.3
Taiwan	31.5
France, red	46.7
France, white	55.96
Holland	32.97
England	52.2
U.S.A.	55.0
Present study	56.1

Table 3
Trace elements analysis (in ppm) of imported and local chalks

Country	Cu	Co	Zn	Cr	Ni	Mn	Pb
Jordan	207	–	83	36	15	10	24
Kore	1350	–	110	910	21	233	41
U.A.E.	20	–	80	50	13	32	26
Japan	35	–	144	44	12	66	29
China, yellow	12	–	69	38	19	39	32
China, white	21	–	92	34	18	85	27
Taiwan	30	–	132	66	18	44	36
France, red	15	8	78	44	19	113	46
France, white	22	12	113	39	26	178	50
Holland	46	–	78	40	14	133	38
England	20	–	69	40	32	50	40
U.S.A.	23	–	75	49	41	67	49
Present study	23	10	73	44	41	62	50

Table 4
Results of experiment 1

Trials	CaCO3 %	Gypsum %	CMC % or PVA	Starch %	ZnO %	H2O %	Remarks
1	90	3	4	2	1	20	bad binding
2	90	3	4	2	1	40	bad binding
3	90	3	4	2	1	60	bad binding
4	90	3	4	2	1	80	bad binding
5	90	3	4	2	1	90	bad binding
6	90	3	4	2	1	100	good binding

Table 5
Results of experiment 2

Trials	CaCO3 %	Gypsum %	CMC % or PVA	Starch %	ZnO %	H2O %	Remarks
1	30	20	20	20	10	100	hard chalk
2	41	17	17	17	10	100	hard chalk
3	50	13	13	13	8	100	hard chalk
4	70	8	8	8	6	100	hard chalk
5	80	6	4	4	6	100	good chalk
6	84	2	6	6	2	100	good chalk
7	90	3	3	3	1	100	good chalk
8	95	1	2	1	1	100	best chalk

Table 6
Results of experiment 3

Trials	CaCO3 %	Gypsum %	CMC % or PVA	Starch %	ZnO %	H2O %	Remarks
1	84	4	5	5	2	100	hard chalk
2	85	3	5	5	2	100	hard chalk
3	86	1	6	5	2	100	good
4	86	0	6	6	2	100	best
5	86	0	7	5	2	100	soft
6	90	0	5	3	2	100	bad

Table 7
Results of experiment 4

Trials	CaCO3 %	Gypsum %	Kaolinite %	CMC %	Starch %	ZnO %	H2O %	Remarks
1	30	30	30	4	4	2	100	bad
2	40	25	25	4	4	2	100	bad
3	50	25	15	4	4	2	100	good
4	55	20	15	4	4	2	100	bad
5	55	15	20	4	4	2	100	bad

Table 8
Results of experiment 5

Trials	CaCO3 %	Gypsum %	CMS %	Starch %	Kaolinite %	ZnO %	H2O %	Remarks
1	20	50	10	10	8	2	100	hard
2	15	70	5	5	3	2	100	hard
3	5	85	3	3	2	2	100	hard
4	1	92	3	3	0	1	100	good
5	2	95	2	2	1	1	100	hard

Table 9
Results of experiment 6

Trials	Grain size (mm)	CaCO3 %	Remarks
1	0.25	86	hard, bad
2	0.15	86	hard, bad
3	0.090	86	moderate
4	0.063	86	good
5	<0.063	86	best

Table 10
Results of experiment 7

Trials	Grain size (mm)	CaCO3 %	Remarks
1	0.25	95	hard
2	0.15	95	good
3	0.09	95	best
4	0.063	95	bad, dusty
5	<0.063	95	dusty

RESULTS AND CONCLUSION

Several samples of blackboard chalk were manufactured and investigations on the factors which affect blackboard chalk production indicate that the amount of water was the most important controlling factor for binding. The best blackboard chalk was prepared with percentage of 100% of water. Water is issued for the hydrolysis and disperson of the binder. Beside the percentage of water, the percentages of calcium carbonate and other essential components were the other controlling factors in the production of blackboard chalk. The best blackboard chalks are with percentage of 86% CaCO3 and grainsize of less than 0.063 mm and 95% CaCO3 and grain size of more than 0.09 mm. So as the grain size decreases, the blackboard chalk would be more soft, but the grains need more binders, also the blackboard chalk became more dustless. For samples with less than 95% or 86% CaCO3, the blackboard chalk would be very hard to be written with. For samples with more than 86% or 95% CaCO3, the blackboard chalk would be very soft and easily broken. As the percent of binders was the controlling variable, the best samples were of 6% carboxy methyl cellulose (CMC) or poly vinyl alcohol (PVA), 6% starch, 2% ZnO. Samples with less than 6% CMc are dusty and show bad binding. Higher % of CMC will give hard blackboard chalk which is not suitable for writing.

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