Regional Symposium on Chemical Engineering (RSCE 2000)
Singapore, 11-13 Dec. 2000

Potential of Malaysian Local Bentonite Applications in an Oil-Well Cement Industry

Ariffin Samsuri, Radzuan Junin, Adil Mohamed Osman
Department of Petroleum Engineering, Faculty of Chemical and Natural Resources Engineering
Universiti Teknologi Malaysia, Skudai, Johor
abumusaabb@hotmail.com

1.0 ABSTRACT

This paper presents the results of experimental studies for Malaysian bentonite application in an oil- well cementing as compare to a world- wide commercially used Wyoming bentonite of USA. The experiments include the performance of class-G cement slurry mixed with bentonite according to API Spec 10 (1990). Treatments (dry & wet processes) have been conducted for the Malaysian local bentonite to up grade its performance. In additional XRD and XRF techniques and methylene blue tests were also carried out for bentonite samples. Compressive strength tested at atmospheric and reservoir conditions, free water and density tests of cement slurry were also determined.

The results of the experiment show that Malaysian local bentonite has very low degree of swelling, therefore the free water increased in the cement slurry, which is higher as compared to Wyoming bentonite. After treatment processes, the free water decreases in the cement slurry with bentonite concentrations increased. The Lahad Datu bentonite gives more slurry density after the treatments. Moreover the addition of Malaysian bentonite to the cement slurry results in significant decrease in the compressive strength.

2.0 INTRODUCTION

Today, wells in the oil industry cover a wide range of depth and temperature. However, cement faces it's toughest challenge underground, in the oil and gas wells where environmental conditions are far more severe. Therefore, the cement compositions are designed to encounter the pressure range from atmospheric to more than 30,000 psi in extremely deep wells, and temperature ranging from below freezing in permafrost zones to 700^0F in deep oil wells. The out come of a cementing job, however, depends on choosing the appropriate cement and additives to cope with the well requirement conditions.

Additives modify the behavior of the cement system, ideally allowing successful slurry placement between the casing and formation, rapid compressive strength development, and adequate zonal isolation during the lifetime of the well (Nelson, 1990). One of the most common materials that have been used for many years as an additive in oil well cementing is bentonite. Bentonite (gel) contains at least 85% of the clay mineral smectite (montmorillonite). Bentonite is used in concentrations as high as 20 percent BWOC. Slurry density quickly decreases with higher bentonite concentration, but its final compressive strength decreases.

Montmorillonite mineral has an expanding lattice i.e. water molecules can be incorporated in and around its structure. This clay mineral is an alteration product of volcanic rocks and the purest deposit, made chiefly of hydrous aluminium silicates of two flat sheets of silica tetrahedra sandwiching one sheet of aluminium octahedra. The addition of bentonite in amounts of 2% to 12% permits the use of more water in the slurries and results in slurry of lower weight, lower strength and lower unit cost. According to its proponents, the main advantages of this type of additive are able to hold the cement particles in suspension, lower slurry density and hydrostatic pressure, better permeability in perforating, lower cost per cubic foot of slurry, and control the free water content of slurry. In addition, bentonite also played an important role as fluid loss control agent when cement is placed across a permeable formation.

Problems with Wyoming bentonite quality and difficulties in determining the quality control methods among manufacture plants and service companies continue to occur which is due to the transportation and storage of imported Wyoming bentonite. So far, this paper is focusing on the study of the potential of Malaysian local bentonite application in an oil-well cement industry.

3.0 TEST PROGRAM AND PROCEDURES

Sabah was sampling area of Malaysian bentonite samples. Samples M4 were collected from Mansuli area at Lahad Datu district, while samples SA5 were from Andrassy area at Tawau district. The commercially world-wide Wyoming bentonite of USA was used for comparison and correlation. Sampling has been carried out by using Dormer auger with the depth ranging from 1-2 meter. The samples were then dried in the oven for overnight, crashed and grounded into the powder form. The powder was sieved into particle size of 75µm. The cement slurry was prepared through the blended of a class-G cement with a dry bentonite sample at concentration of 2% to 16% BWOC and evaluated its free water content, density and compressive strength performance according to API Spec 10 (1990). The cement slurry has been prepared according to API Spec 10 Section 5. In addition, local bentonite has been treated with Na_2CO_3 through dry and wet processes in order to improve its performance.

Compressive strength tester had been used for compressive strength determination and free water content was measured in 250-ml graduated glass cylinder. Density balance is a device suited to estimate the density of cement slurry. In addition, characterizations of bentonite samples have been examined by using XRD & XRF techniques. The SIEMEN D-500 X-ray diffractometer unit was used to determine the mineralogical contents of the bentonite samples. While automated Phillips PW1480 X-ray fluorescence spectrometer has been used to determine the chemical contents of the bentonite materials. Moreover methylene blue test was carried out according to API 13B (1984) to estimate the cation exchange capacity (CEC).

4.0 RESULTS AND DISCUSSIONS

4.1 Mineralogical & Chemical Composition

From Table 1 it can be seen that the Wyoming bentonite samples (WY-BEN) contains more montmorillonite mineral than the local bentonite. In addition, Malaysian bentonite samples contain impurity minerals such as quartz, kaolinite, illite and feldspar.

XRF data in Table 2 shows the amount of SiO_2 is higher in all bentonite samples, with Wyoming bentonite contains less than the local bentonite, which indicated the presence of quartz as previously discussed. The Na_2O amount is higher in Wyoming bentonite than untreated local bentonite, but the Na_2O amounts increased in treated Malaysian bentonite, especially from the dry process samples. The Fe_2O_3 amount is higher in all Malaysian bentonite samples indicating the presence of hematite mineral.

TABLE 1: Semi- quantitative Mineral Compositions Analysis of Bentonite Samples by X-ray Diffraction

Minerals	Wyoming bentonite (WY-BEN)	Local bentonite before treatment (SA5-BT)	Local bentonite after dry process (SA5-DP)	Local bentonite after wet process (SA5-WP)	Local bentonite before treatment (M4-BT)	Local bentonite after dry process (M4-DP)	Local bentonite after wet process (M4-WP)
Montmor-illonite	* * * *	* *	**	*	*	*	*
Quartz	* *	* * *	***	***	***	***	* * *
Feldspar	Nd	Nd	Tr Orthoclase	* albite	* muscovite	Tr Muscovite	* muscovite
Kaolinite	Tr	*	*	**	*	*	*
Others	Tr Illite	* illite	* illite	Nd	* illite	* illite	* illite

Key :- * * * * . dominant ; * * * : major ; * * : appreciate ; * : minor/ small; Tr: trace ; Nd : not detected

4.2 Cation Exchange Capacity

Table 3 lists the average CEC of various bentonite samples. It shows that untreated Malaysian bentonite samples have lesser values of CEC (25 &30 meq/100g) due to the presence of other minerals such as quartz, kaolinite, illite and feldspar, which have been improved after treatments, due to the presence of sodium content in its structural composition during ionic exchange (Ca^{+2} replaced by Na^{+}). Table 3 also shows that the treated Malaysian bentonite samples with dry process have higher values of CEC (40 & 45 meq/100g) as compared with the wet process samples (30 &40 meq/100g) but still lower than Wyoming bentonite.

4.3 Free Water Performance

It has been shown in Figure 1 that, when Malaysian bentonite was added to the cement slurries, the free water content increased, due to the presence of hematite mineral in its structural composition as previously discussed.

TABLE 2: Chemical Composition of Bentonite Samples by X-ray Fluorescence

Compound	Local bentonite before treatment SA5-BT	Local bentonite after dry process SA5-DP	bentonite after wet process SA5-WP	Wyoming bentonite WY-BEN	Local bentonite before treatment M4-BT	Local bentonite after dry process M4-DP	Local bentonite after wet process M4-WP
SiO_2	55.22	48.20	63.06	65.48	63.10	53.86	55.52
TiO_2	0.70	0.60	0.68	0.13	0.71	0.62	0.69
Fe_2O_3	8.35	7.21	7.60	3.79	7.11	6.79	8.14
Al_2O_3	22.21	19.26	16.60	18.77	16.94	16.10	20.59
MnO	0.04	0.03	0.06	0.02	0.07	0.05	0.04
CaO	0.53	0.49	0.20	1.18	0.19	0.27	0.50
MgO	0.55	< 0.01	1.04	1.04	1.12	0.54	0.50
Na_2O	< 0.01	9.96	1.30	2.03	0.29	7.73	2.42
K_2O	0.47	0.46	2.29	0.78	2.35	1.60	0.75
P_2O_5	0.02	0.01	0.03	0.06	0.03	0.02	0.02
L.O.I	11.92	14.61	7.15	6.63	8.12	11.46	10.85
Total %	100.01	100.83	100.01	100.21	100.03	99.04	100.02

TABLE 3: Cation Exchange Capacity (CEC) Data

Samples	CEC values for Untreated Bentonite (meq/100g)	After Treatment Processes	
		CEC values for Dry Process (meq/100g)	CEC values for Wet Process (meq/100g)
SA5-Local Bentonite	30	45	35
M4-Local Bentonite	25	40	30
WY-BEN-Wyoming Bentonite	70	-	-

This heavy mineral has no ability to absorb water; hence, it will reduce water absorption ability of Malaysian bentonite. Free water content has been decreased in cement slurry with increasing the amount of Wyoming bentonite due to presence of higher montmorillonite mineral content, which has higher swelling capacity.

The free water performance in Figure 1 also shows that all Malaysian bentonite samples performance improved after had been treated with Na_2CO_3, due to increase of sodium content in their structural compositions. It is also shown in Figure 1 that the higher amount of treated Malaysian bentonite added to the cement slurry, the lesser would be that the free water content of cement slurry provided the amount is less than 2% BWOC. If the amount of bentonite added is more than 2% BWOC, the free water increases up to 8% BWOC of treated bentonite is added, after which the free water decreased with increases amount of bentonite added. As shown in Figure 1 the dry process Malaysian bentonite samples had better control of free water content compared to wet process samples, but not as good as Wyoming bentonite.

4.4 Density Determination

In general the density of cement slurry will be decreased, with higher percentage of bentonite. It is in agreement with Nelson (1990) that the slurry density decreases with bentonite concentration increased.

Figure 2 shows the density of cement slurry mixed with Malaysian bentonite samples before treatment is heavier than the density of cement slurry mixed with Wyoming bentonite. This can be attributed to the highly presence of hematite mineral in the structural composition of Malaysian bentonite samples rather than Wyoming bentonite sample. Figure 2 also shows that the density of cement slurry with treated local bentonite is lowered. This is due to the increasing of the sodium contents and slightly decreasing of Fe_2O_3 in their structural compositions as previously discussed. It is also shown in Figure 2 that Malaysian bentonite samples of dry process having better cement slurry density rather than wet process samples, but not much better than Wyoming bentonite samples.

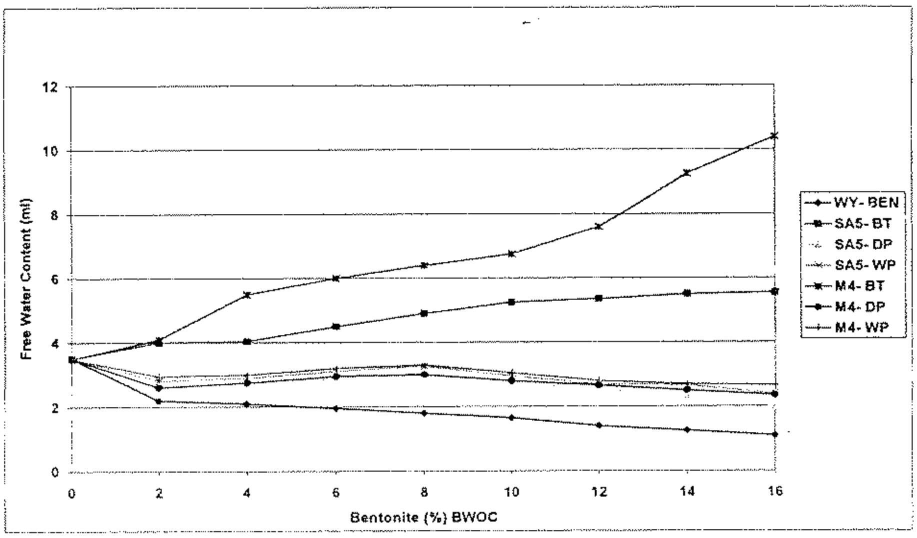

Figure 1: Free Water of Cement Slurry with Various Amount of Bentonite under 24 Hours Curing Period at Atmospheric Condition.

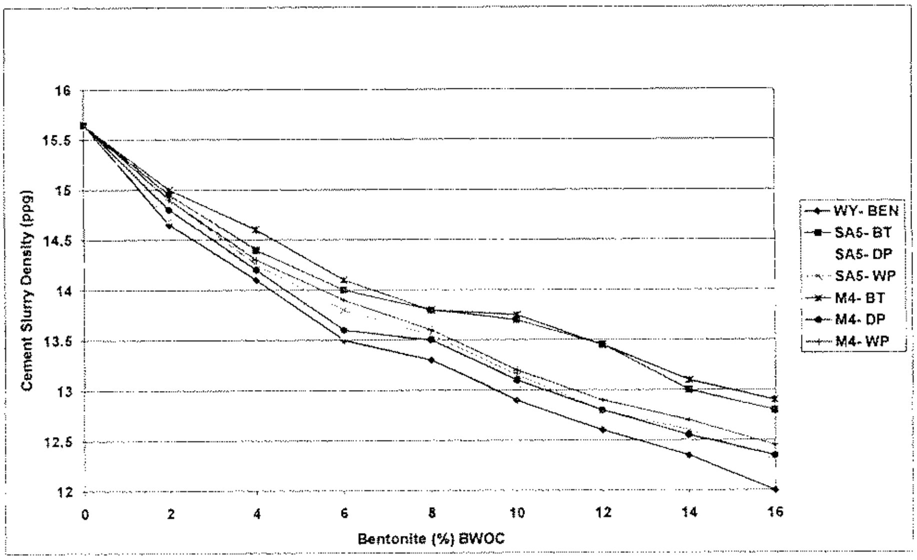

Figure 2: Density of Cement Slurry with Various Amount of Bentonite under 24 Hours Curing Period at Atmospheric Condition.

4.5 Compressive Strength Performance

It can be clearly observed that compressive strength of cement set decreases with increase in bentonite concentration. This result is in agreement with Nelson (1990) quoted that as the density of cement slurry with bentonite decreases, the compressive strength also decreases. Figure 3 shows that a higher amount of untreated Malaysian bentonite in the cement slurry, the lesser will be the compressive strength rather than Wyoming bentonite samples. This is due to the cement slurry with Malaysian bentonite has higher water cement ratio, more free water and fluid loss content therefore less compressive strength.

Figures 4 and 5 show that the compressive strength of cement slurries is increased with increasing amount of treated Malaysian bentonite samples, due to increase of sodium contents in their structural compositions. Figure 4 and 5 also shows that dry process samples have improved the cement slurry compressive strength better than the wet process samples.

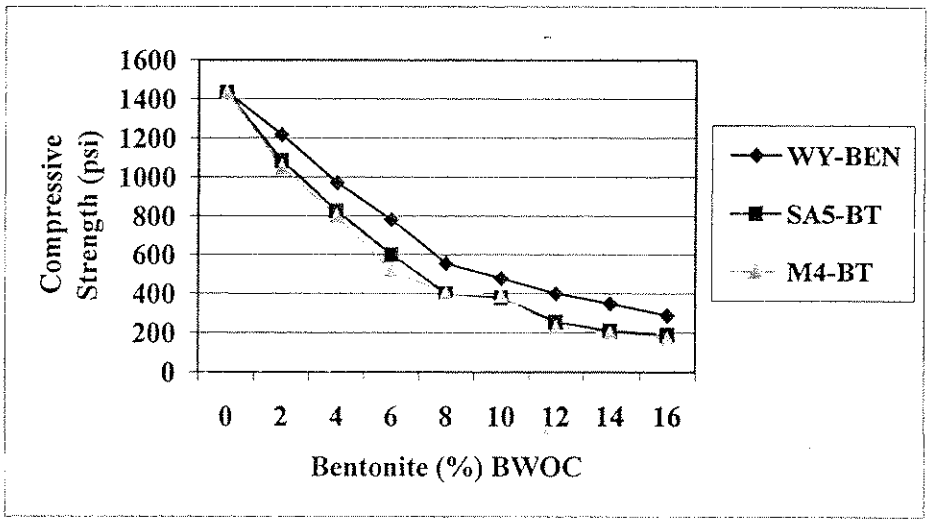

Figure 3: Compressive Strength of Cement Slurry with Various Amount of Bentonite before Treatment Process under 24 Hours Curing Period at Atmospheric Condition.

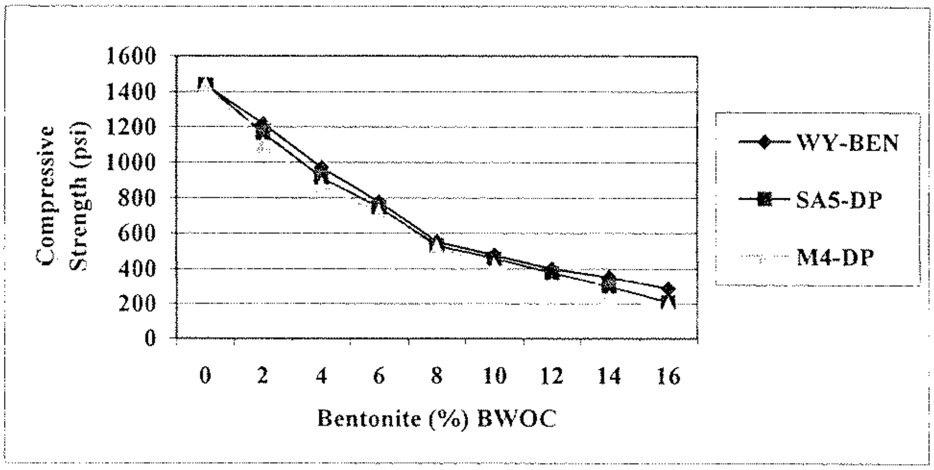

Figure 4: Compressive Strength of Cement Slurry with Various Amount of Bentonite after Dry Process under 24 Hours Curing Period at Atmospheric Condition.

5.0 CONCLUSIONS

From the laboratory investigation, it can be concluded that:
1) Local bentonite samples contain less amount of montmorillonite mineral and more impurity materials such as kaolinite, illite, quartz and feldspar, while Wyoming bentonite is considered as high- quality bentonite
2) Performance of untreated local bentonite as a free water controller is not as good as a Wyoming bentonite but can be improved through dry or wet treatment processes if the amount used is not more than 2% BWOC.
3) The main function of Malaysian bentonite as an extender can be improved through treatment processes.
4) The compressive strength of cement slurry with Malaysian bentonite can be further improved through dry or wet treatment processes.

6.0 NOMENCLATURE

API Spec10 = American Petroleum Institute Specification 10.
BWOC = By weight of cement.

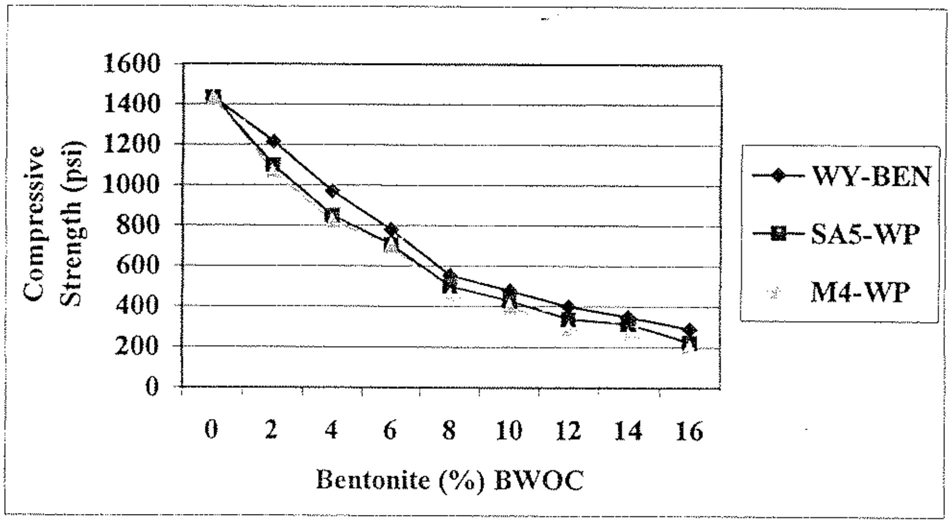

Figure 5: Compressive Strength of Cement Slurry with Various Amount of Bentonite after Wet Process under 24 Hours Curing Period at Atmospheric Condition.

CEC = Cation Exchange Capacity.
WP = After wet process.
WY-BEN = Wyoming bentonite sample.
XRD = X-ray diffraction.
XRF = X-ray fluorescence.

7.0 REFERENCES

API Specification 10 (1990). *Specification for Materials and Testing for Well Cements*. **pp 14-19**. Washington DC 20005: Issued by American Petroleum Institute Production Department.

API Specification 13B (1984). *Standard Procedure for Field Testing Drilling Fluids*. **pp 17-18**. Washington DC 20005: Issued by American Petroleum Institute Production Department.

Nelson, E. B (1990). *Well Cementing*. **pp 3-1, 3-9**. Elsevier Science Publishers B.V., Netherland.