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Development Brake Development of Suitable Calcined Refractory Clay for Automobile Brake Pads

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Abstract
Alumino-silicate fireclay material was found within the equatorial region of Ekiti state of Nigeria. From Ijero-Ekiti, fireclay samples were explored, exploited and developed into automobile brake pads. Eight samples were taken from 5 to 30 metres downward at various pits to prevent unwanted foreign materials. Specifically, these samples were examined and found to be characteristically homogeneous in physical, mechanical, mineralogical and chemical composition. 30 per cent of the unwanted foreign materials from the fireclay were technically removed with above 45 micron sieve using a wet sieving method. 70 per cent of the purified clay of less than 45 micron sieve was eventually used as beneficiated fireclay material. After the purification, sample clay obtained was finally calcined at 1500^0C temperature for clay structural stability and prevention of excessive clay shrinkage. The refractory clay material was eventually made into various is batches using a mathematical model. Material composition fomula used was technically based on range of grain particle sizes (30 to 70 per cent) grog or calcined clay; and beneficiated clay range of particle sizes of 70 to 30 per cent as the binding agent respectively. Thereafter, batch material compositions were homogeneously mixed and properly wedge together in a pugged mill before they were hydraulically pressed with 1000kg/mm^2 with a designed steel mould. Automobile brake pads made were characteristically tested and found suitable for light (Cars) vehicles usage 80 per cent efficiency.

INTRODUCTION

The overheads incurred in maintaining the Nigerian democratic government is too expensive. For example, 25.1 per cent of federal government budget from 1999 to 2012 was yearly taken by Nigerian senators and House of Representatives only. The basic salary of the lowest earning legislator without taking into account perquisites and other unrecorded earnings exceeds salary of the present president of the United State of America (Soyinka, 2011). Nigerians have more than thirty political parties and no single political party raises any fundamental or justifiable questions. Hypothetically, would it not better if Nigerian legislators serve on part-time basis to reduce the statistics of political morbidity through a diminished monetary attraction? Asides, 70 percent of Nigerian National revenue was yearly consumed by the civil Servants and the executive arm of federal Government. Therefore, 30 per cent of the remaining revenue could only be used for national infrastructural facilities and other development in Agriculture, Industries, health and education for about 160 million Nigerian populations with high poverty rating and unemployment. Therefore, there is a serious need to develop the Nigerian manufacturing sector in other to develop economy speedy.

Asides, Nigerian Industrialization problems employment in Nigeria less had been a serious problem, most especially on unemployed able graduates. Research shows reseNigerian youth could eventually cause bloody revolution with the high rate of unemployment from (1999-2013) of democratic years. Technically the core problems of Nigerian development are found in Nigerian leadership qualify that is very low; managing the vast resources and using the Nigerian researches obtained from institutions and individuals for Nigerian upliftment. Significantly, Awolowo Obafemi and Ahmadu Bello became Nigeria's heroes because of their entrepreneurship and developmental programmes management in 1950-1967. Continuously, research institutions and respectable academic journals are appreciating these two leaders with discipline, qualitative leadership and entrepreneurship. Comparatively, during this period priorities were given to natural resources management and industrial development; rural integration and employment; qualitative health and schooling (Guardian, 1987; and New Nigeria 1987). Similarly, Singapore, Hong Kong, South Korea and Taiwan are nations leading the world in manufacturing; information technology and finance because of their committed leaders in discipline, leadership and entrepreneurship for national development with emphasis on global competitiveness (The Nation,2012).

Nigeria endowed with over 40 different types of minerals that are mainly metallic and non metallic minerals, gemstones, some strategic metallic minerals such as lead-zinc. Available evidence and statistics have confirmed that those natural resources are largely untapped and still exist majorly in crude forms in their natural deposits. This is because Nigeria depends solely petroleum resources as the main source of national revenue over the years. The trend contributes to the poor development of the solid mineral sector. With the unpredictable pricing regime in the international petroleum market and the shifting to renewable sources of energy as alternatives to fossil fuels; Nigerian government is placing priority on the development of the mineral sector as

alternative source of national revenue to cushion the effect of the current development on the nation's economy. The mineral sector holds huge potentials to generate employment, catalyze industrialization and provide alternative source of national revenue, if effectively developed (RMRDC, 2010)

Between 2010 and 201, the federal Government earned about 1.7billion naira from the solid minerals sector. The government attributed the earnings to its advocacy and mass mobilization campaigns on economic diversification.

Beside Complimentary revenue from oil and gas, revenue from the solid mineral sector could ensure even development in the country as every part of the country produces one solid mineral or the other. The sharing of the derivation fund to beneficiary states would be based on the 13 per cent Derivation indices using 2010-2011 solid mineral revenue contribution by the states within Nigeria. Unlike oil and gas, solid minerals were found in every state which call for even development (Ujah, 2012)

Ekiti-State vast mineral resources have not been fully appraised because of insufficient studies. Previous works have identified''. Some mineral deposits but largely unevaluated. Geologically, localization of these minerals is of basement and quaternary alluvial deposits, other occurs in both types. Clays are found in many localities in Nigeria, especially in Ekiti-state. The clay is mined, purified and utilized for industrial development of automobile brake pads. However, clay could also be used for refractory bricks, electrical insulators, pots, sanitary wares e.t.c. with the industrial incentives of the federal and state government, the strong political will for development, favourable industrial climate and recent evolution of the new national policy on solid minerals able investors should be prepared to set up industrial companies for the exploration, exploitation and manufacturing of clays and other minerals with Ekiti state or in anywhere in Nigeria. (RMRDC, 2010, OJO, 2009 and Faluyi, 2004)

MATERIAL AND METHOD

Research carried out clay on Ekiti clays in Nigeria suggested various purification methods for the commercial clay deposits as found at Ise, Ikere, Ado, Ijero and Igbara odo from 1942 till 2012 respectively (Aderiye, 2007). Therefore, a simple, inexpensive beneficiation process was designed and constructed locally for this research project. Considering the quality and quantity of the fireclay at Ijero-Ekiti, interrupted electricity and unemployment Nigeria, manual machine that could solve the aforementioned problems and thereafter employed Nigerians was used in the production. Geological survey and exploration of Ijero-Ekiti clay deposit was initially made. The clay was exploited and used for brake pad development. Totally, 100kg samples were subsequently taken from eight cardinals (North, East, South, West, North East, South East, South West, and North West) areas.

During exploitation, the overburdens of top layers consisting of wood, trees, humus soil and organic materials were completely removed. Between the depths of five of thirty meters clay was obtained. Purification process was done before the desired clay was calcined at 1500^0C temperature in a designed and constructed stationary furnace. The clay was vitrified and annealed for thermal and structural stability (figure 1). Desired clay particles were eventually taken wit 45micron sieve at 70%; while 30% of unwanted and oversize clay particles and other materials were technically removed (Figure 2). Significantly, safety measure in automobile industry is taken seriously (Kayput, 2007). Therefore, clay quality or any material to be employed must be qualitatively treated for the required standard in brake pad development. Although consideration was taken on material costing and profit derived after brake pad development. Yet material used and quality control employed was not compromised however. After material pre-treatment by wet sieving method, the purified clay sample obtained was further examined and analyzed. Atomic Absorption Spectrophotometry (A.A.S) device was for the clay examinations and chemical composition analyses where principal chemical oxides present were presented on Table 1. Calcination process was further made on the beneficiated clay by heating the material into grog or chamotte at 1500^0C temperature with a locally designed and constructed stationary furnace. Annealed material at 0^0C temperature was examined further to know the major mineral present in the Calcined clay with the use of X-ray Differactometer (XRD). Result obtained from the experiment was presented on Figure 4. With the use of mechanical crusher grog was crushed and sieved properly to obtain calcined particle sizes between 45 to 200 microns. For efficiency, it is important to use ball mill for effective grinding to produce fine particle size for batch composition. (Kingery, 1976). Therefore, batch calculations and compositions were produced with the use of a mathematical formula of proportional ratio (Table 1).

Although various techniques being used now to shape high tech ceramics huge been employed by various porters for millennia, yet, most methods have been somehow redefined for current high tech applications; especially for the new ceramic materials with their commercial trends. For this research, the grog, beneficiated clay and water constituent were prepared in a desired purity with various required particle sizes. Hydraulic dry pressing was employed with a pressing was employed with a pressure of 300Mpa to maximize the density of the compact. The beneficiated clay was used as a binder which acted as a plastic material (Figure 2) that held the various fractional grains together during shaping. Water also improved the moulding and acts as a lubricant in the shaping method employed. After pressing, both punches moved upward until the bottom punch was level

with the top of the die; and the top punch was cleared of the powder-feeding mechanism. The compact was then ejected. The bottom punch lowered. The production cycle was rejected for the 16 batches prepared. (Table 3) commercial production was considered for Ekiti state of Nigeria that has the deposit where Ijero –Ekiti fireclay was mined because the dry pressing process was so simple and involved low capital equipment costs; and most widely used for high volume forming process during experimentation (Wright, 1990) it was adopted for the pilot plant scheme for the prototype automobile disk brake pad.

Poly(Vinyl alcohol)(PVA) provides a high green strength, and poly (ethylene glycol (PEG) provides a high green density. These two binders that are the most popular binders for dry pressing powder could have been employed. However, beneficiated clay was used because of material cost and other technical consideration, such as blisters, cracks or distorting defects which affect both mechanical strength and other characteristic properties of the automobile brake pads.

Water of preparation and crystallization eventually removed from the shaped clay. The rest of the firing process caused structural changes and transformations in the brake pad to be produced (Table 4). For this project, Ijero-Ekiti clay, the beneficiated clay and water used as binder were oxidized to form H_2O, CO and CO_2 respectively when the green compact was heated in oxidized atmosphere in a kiln. Binders used present no problems during firing at 800^0C temperature.

RESULTS AND DISCUSSION

Today in Nigeria, 98% of automotive brake pads are been consumed annually by the automobile industries and the associative trading companies. Besides, above 12 billion naira is been employed for such importation yearly. Comparatively, India, Brazil and China are developing countries that are locally producing and consuming about 98% of their automotive brake pads annually.(Aderiye,2012). Yet, 98% of automotive brake pad materials could be obtained cheaply in Nigeria (Amarem, 2010). The theoretical and empirical works with their various technical analyses on current automotive brake pad systems and developmental studies as provided by researches such as Dolani (1977); Giri (2008) and casellas et al, (2005) have been carefully and intensively studied. Technically, these selected studies were appreciated, simplified and adopted for this research usage(Figure 1) as the flow chart for the research.

Results of the examinations made on the Ijero-Ekiti fireclay samples were analyzed for characterization benefits of automobile brake pad friction material development. Interestingly, the fireclay was found to be acceptable has shown (in Tables 1 to 5 and Figures 1 and 2) respectively. The prime significant of this study therefore is the local use of beneficiated Ijero-Ekiti fireclay deposits. Adoptations of the appropriate and sustainable technology with management are other important factors instead of employing a complex and very expensive equipment with foreign technology that would be very difficult to manage and maintain by Nigerians.

Ijero-Ekiti fireclay deposit is a very large deposit with several millions of tones. Commercially, it is very viable sedimentary clay that could be opened mined and transported to the industrial site for further processing into the automobile pad for various cars and trucks. Fireclay as a heavy mineral material that requires heavy trucks or railway for transportation to the industrial site, due to the transportation cost of this clay material with other vehicle maintenance problems, it is reasonably suggested the automobile brake pad industry be profitably established at Ijero-Ekiti for the clay easy exploration, exploitation, transportation and profitable production and revenue. The mineral clay could be used for 100 years at usage rate 100 tonnes per day. Aside, associative mineral materials could be processed further with the fireclay. Resultantly, this would bring in localization of industries that would eventually industrialize Ekiti state of Nigeria rapidly within a decade year.

Two methods of suntering and clay powder compaction were technically factorized in this study. Suntering process was used to transform the fireclay grains into solid body through heating and densification without melting. Therefore, controlled particle package was considered (Table 3) through the mixture of various grains of 1 to 125 micron sizes. Nanomaterials are very reactive (Kang, 2005). So when the clay particles of 1 to 18 micron sizes were sintered at lower temperature, glass phase was obtained to bind further the grain boundaries of coarse sizes of 18 to 75 microns within the batch composition. Researcher shown sintering material for long period for improved characteristic properties is impractical. (Maximenko, 2004 and Kang, 2005). Therefore, the main feature of sintering process was the joining together of clay particles without proper melting (Table 4).

Due to technical and economical reasons clay powder compaction method was selected from other considered methods. The adopted method was technically modified to suit the automobile brake pads production with a hydraulic press machine. However, unwanted pores were avoided with the mixture of various particles from 1 to 125 microns within each batch composition made. Thermodynamically, both Physics and chemistry played special roles in the phase transformation of the clay particles that resulted into structural form called pad with increased temperature. Chemical reations between particles of 1 to 125 microns were rapid because they were generally fine grains with large surface areas for chemical reactions. With increased temperature solid

reactions occur earlier in less than 18 microns before the coarse grains. This responsible for the structural phase formed through fine grains were responsible major grains binding and compactness of the brake pad wearing resistance.

QUALITY CONTROL AND ASSURANCE

Characteristically, to understand the nature, behaviours and properties of automatic brake pad made, it is essential to have knowledge of the compound structure and composition. For Example, Material grain size decreases with increases in strength. But material particle is determined by the powder particles and its consolidation, grain boundaries, material purity, and porosity e.t.c. (Dagwa, 2006). However, these research batch specimens were made in laboratory with composition as shown in Table 3. While optimal manufacturing parameters used for the experimental quality control and assurance formulations were extracted from certain research work activities. (America, 2010, Aderiye, 2007 and Dagwa, 2005). Respectively.

Sixteen batch specimens were mould with pressure hydraulically pressed; fixed at 900^0C and annealed from 900^0C to 0^0C temperature. Thereafter, quality control tests use carried out as stated on table5. The Table summaries all the twenty two tests with their results for the research brake pads; and compared them with the result of other control commercial brake Aderiye, 2012).

Resultantly, Hardness tests suggest less hardness produces lower adverse effect or motor drum or disk rotors usually made of cast iron; ceramic matrix composites and reinforced carbon-carbon. The experimental brake pad made is satisfactory when compared with others on the Table 5. The izod impact strength of friction materials ranges from 0.0115 to 0.0154 J/mm^2 (Dagwa, 2006). This shows the fireclay pad produced has acceptance impact strength that is also an advantage to brake pad shock resistance. From the results on the specific heat capacity, the clay brakepad has more than the required energy to heat its unit mass with 1^0C temperature. This indicates that pad could absorb excessive heat from the brake system.vif brake is applied suddenly at very high speed. Porosity tests for the sixteen batches of the clay brake pads were from 8 to 10%. Analytically, frictional materials with high porosity has a tendency to decrease noise pollution; but with an increase wear propensity is assured. Also fireclay being a refractory material acted as flame retardant in the brake pad made. From the test conducted with a muffle furnace at 900^0C for ten minutes repeatedly for five times. The clay pad did not burn or distort as observed. It shoes the brake pad also has reasonable thermal shock resistance.

Thickness swell both in water and motor oil test weremade per 24hours. The results presented for both water and motor oil soaked the claybrake pad as presented on Table 5. Water absorbtion level of the brake pad shows higher to the two different motor oil used after the 24hours of soaking. The difference in the absorbtion levels was due to fluidity or low viscosity of water and surface tension as compared with motor oil used the two motor oil used in this research work. The thermal conductivities of friction materials range from 0.47 to 0.804W/mk. However, the thermal conductivity of the clay material was found to be 0.6W/mk. Brake system associates like iron pad plates and rotor improved thermal conductivity through perforated holes for insulating metallic materials but fireclay absorbs heat and is a weak conductor. The compression strength test results are presented on table 5. Clay pad produced was 110 Mpa. This value is within the recommended values. Compression force squeeze the tertial, therefore, its strenghth should be enough to present stress and strain from deforming size, shape or break the clay pad.

While the co-efficient of friction of the clay pad is within the standard values of 0.3-0.6 as recommended for vehicle brake pads. It's a dimensionless indication of the friction qualities of one material sliding over another (Blau, 2001). Ceramics fail after 0.1% strain, this necessitates that tensile specimens be perfectly aligned in order to avoid the presence of bending stresses which are not easily calculated. Therefore, an ASTM standard C1161 of three point loading scheme for measuring the stress-strain behavior and flexural strength of brittle ceramic (Callister, 1997). The tensile test result for the fireclay brake pad was obtained by using the 3 point loading system. (Table 5). The tensile strengths of ceramics are about one-twenth of their comprehensive strengths. The flexure test is a reasonable substitute for the tensile test. The stress at fracture using this flexure test, known as flexural strength decreases exponentially with volume fraction porosity. The shear strength result for the clay pad is presented on Table 5 with an average value of 2.5 Mpa as compared with other types that have above standard value of 2.10Mpa at room temperature. While the average wear of the claypad was found at 3.8mg/application.

CONCLUSION

Summarily, Ijero-Ekiti fireclay is a potential nonrenewable mineral resource with profitable concentration of both alumina and silica minerals as found within the average crustal severally. However, Magnesium oxides, potassium oxides and calcium carbonates were also available. Intensively, Ijero fireclay samples were technically examined extensively analyzed and developed into hydraulic brake pads in Comparism. It was found that organic brake pad did not last long. While its replacement, the semi-metallic pads lasted longer, but wear on

brake drums and rotors was unacceptable. The clay pad produced by this study provides extended pad life without excessive rotor wear; environmentally and medically friendly. It was research upon and found that it is economically cheaper than the Asbestos, organic and metallic brake pads commonly sold in the global market. For excellent performance these brake pads cannot compete with the clay pad currently developed in this study.

Conclusively, both the mineral extractive and brake pads manufacturing industries should be encouraged to be established within the Ijero-Ekiti local government area of Ekiti State in Nigeria by the potential investors, Besides, the nicely package of incentives provided by the governments of Federal, State and Ijero-Ekiti local government area. Henceforth, emphasis should be more on finance to speedily help in the extractive and manufacturing industries establishment. Finance structures all other significant factors in industrial location. Therefore, interested investors should be encouraged through favourable loans, partnership and grants as found essential by the research work.

Disk brake is currently the best braking system available at the moment. It is found in locomotives in Jumbo jets, aside from various automobiles. This is because of its favourable characteristic properties. It is recommended that further research work should be done on ceramic pads with the use of glass matrix to meet improved broad temperature range, low noise, improved wear life and less dust. Today's cars and light trucks need brake pads that operate at high temperatures; withstand stresses and very efficient.

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TABLE 1: CHEMICAL COMPOUNDS PRESENT IN THE IJERO-EKITI FIRECLAY SAMPLES RAW FIRECLAY

	ELEMENTS	**COMPOUNDS**	**RAW FIRECLAY DEPOSIT**	**BENEFICIATED FIRECLAY**	**CALCINED CLAY**
1	Al	Al_2O_3	40.001	40.00	40.8
2	Si	SiO_2	50.04	50.05	50.0
3	K	K_2O	1.03	0.93	0.961
4	Ca	CaO	0.05	0.50	0.35
5	Sc	Sc_2O_3	0.03	0.01	0.000
6	Ti	TiO_2	0.40	0.22	0.046
7	Cr	Cr_2O_3	0.020	0.015	0.019
8	Mn	MnO	0.500	0.580	0.010
9	Fe	Fe_2O_3	0.041	0.061	0.008
10	Ni	NiO	0.002	0.35	0.409
11	Cu	CuO	0.031	0.003	0.020
12	Zn	ZnO	0.650	0.90	0.026
13	Ga	Ga_2O_3	0.013	0.007	0.0082
14	Rb	Rb_2O	0.045	0.001	0.021
15	Y	Y_2O_3	0.025	0.002	0.019
16	Zr	ZrO_2	0.871	0.010	0.059
17	Ru	RuO_2	0.057	0.001	0.0078
18	Re	Re_2O_7	0.905	0.35	0.409
19	Os	OsO_4	0.025	0.010	0.011
20	Au	Au	0.217	0.50	0.019
21	Mg	MgO	3.30	4.00	4.800
22	S	SO_3	1.63	1.50	2.00

TABLE 2: COMPARATIVE COMPOSITION OF VARIOUS AUTOMOBILE BRAKE PADS AND OTHER CLAY BRAKE PAD.

	ELEMENTS	COMPOUNDS	CLAY PAD	BENZ	TOYOTA	PEUGEOT
1	Al	Al_2O_3	40.40	3.30	0.22	2.82
2	Si	SiO_2	50.03	12.98	2.05	17.16
3	K	K_2O	0.94	0.55	0.15	1.97
4	Ca	CaO	0.43	1.14	47.90	1.56
5	Sc	Sc_2O_3	0.00	0.00	0.00	0.00
6	Ti	TiO_2	0.13	1.20	0.10	1.60
7	Cr	Cr_2O_3	0.02	0.00	0.76	0.00
8	Mn	MnO	0.30	0.17	0.14	0.00
9	Fe	Fe_2O_3	0.03	36.46	5.28	15.30
10	Ni	NiO	0.38	0.04	0.20	0.07
11	Cu	CuO	0.01	0.16	0.09	0.12
12	Zn	ZnO	0.46	0.23	0.17	0.29
13	Ga	Ga_2O_3	0.01	0.00	0.00	0.00
14	Rb	Rb_2O	0.01	0.00	0.00	0.00
15	Y	Y_2O_3	0.03	0.00	0.00	0.01
16	Zr	ZrO_2	0.00	1.11	0.20	0.7
17	Ru	RuO_2	0.38	0.00	0.40	0.00
18	Re	Re_2O_7	0.01	0.00	0.00	0.00
19	Os	OsO_4	0.26	0.00	0.00	0.00
20	Au	Au	0.02	0.00	0.00	0.00
21	Mg	MgO	4.40	0.93	7.02	15.07
22	S	SO_3	1.80	11.4	1.80	14.10

TABLE 3: Mathematically relationship used for the batch calculation and composition for automobile brake pad development

IJERO-EKITI FIRECLAY PARTICLE SIZE

No	Class	Particle Range Micron (um)	Mean(um)	Sieve used(um)	Ratio used (%)	Batches used (%)					
1	Very coarse G0:B75	125 + 75 microns	100	125	25	1	G70:BO	6	G20:B50	11	G45:B2516
2	Coarse	75 + 45 microns	60	75	25	2	G60:B10	7	G10:B60	12	G35:B35
3	Medium	45 + 25 microns	35	45	25	3	G60:B20	8	G0:B70	13	G25:B45
4	Fine	25 + 18 microns	22	25	25	4	G60:B30	9	G65:B5	14	G15:B55
5	Average	68 + 41 microns	54	68	25	5	G60:B40	10	G55:B15	15	G5:B65

NOTE – Grog represents G
Beneficiated clay represents B
2% of Water added for batch

4. Chemical reactions and decompositions of 0 degree to 900 degree Temperature for the automobile brake pad development.

No	Temperature 0^0C	Decompositions and reactions of materials
1.	15 to 100^0C	preparatory water and humidity water were evaporated from the materials used in the kiln.
2.	100 to 400^0C	water of crystallization from materials was liberated
3.	400 to 600^0C	kaolinite ($Al_3SiO_5(OH)_4$) was formed.
4.	400 to 600^0C	kaolinite dehydrated and free quartz changed form. Gases of $S0_2$, CO_2, CO were liberated. Metal kaolin (Al_2O_3
5.	700 to 900^0C	Sintering occurred. All gases liberated recycstallization occurred. Liquid phase helped material binding and contraction. Pores and volume shrinked with densification.
6.	900 to 0^0C	Annealing of the Material to release strains and stresses from the pad.

	Temperature 0^0C	Reactions of gases and metallic compounds
7.	400 to 700^0C	$S + O_2 - SO_2$ $C + O_2 - CO_2$ $C + O - CO$
8.	700 to 900^0C	$FeS_2 + O_2 — FeS_2 + SO_2$ $MgCO_3 - MgO + CO_2$ $4FeS + 7O_2 - 2Fe_2CO_3 + 4SO_2$ $Fe_2(SO_4)_3 - Fe_2O_3 + 3SO_2$ $CaCO_3 - CaO + CO_2$ $CaSO_4 - CaO + SO_3$

Table 5: quality control and assurance of Ijero fireclay brake pad and other commercial brakepads.

Required properties Characteristic	Quality level and Assurance for various brake pads.		
	CLAY	ABESTORS CLAY	ORGANIC BASED
1. Linear shrinkage (%)	5%	-	- 21.7%
2. Apparent porosity (%)	8%	7.6%	1.65g/ml
3. Bulk density (%)	1.7 g/ml	-	-
4. Specific gravity (g/ml)	1.8 g/ml	1.89g/ml	
5. Resistance to slag	98 %	-	Smooth
6. Shape after firing at 900^0C	No	-	Greyish 1.46w/mk
7. Surface texture after firing at 900^0C	Warping	Smooth	1907J/kgf
8. Colour after firing at 900^0C	Smooth	Greyish	92brinell
9. Thermal conductivity (W/mk)	High	0.54w/mk	11Mpa
10. Specific heat capacity (J/kgf)	Brown	1344J/kgf	0.077J/mm^2
11. Hardness brinell at 3000kg/f	0.6W/mk	110brinell	6.8mpa
12. Modulus of Rupture (Mpa)	1344J/kgf	-	2.45mpa
13. Impact Strength (Mpa)	101brinell	0.11J/mm^2	103.5Mpa
14. Tensile Strength (Mpa)	11.4Mpa	-	0.43
15. Shear Strength (Mpa)	0.01J/mm^2	5.46Mpa	46%
16. Comprehensive Strength (Mpa)	6.1Mpa	110Mpa	4.4mg
17. Coefficient of Static friction	2.5Mpa	0.4	12.38%
18. Flame resistance test.	110Mpa	9%	1.32%
19. Average Wear (mg/application)	0.45	3.8mg	1.00%
20. Thickness Swell in Water per dey (%)	2%	4.29%	-
	3.8mg	1.3%	
21. Thickness Swell in Motor Oil (SEA 40)	2.5%	30%	
	1.2%	-	
21B. Lubicon Super XV 20W/50 (%)	1.0%		
22. Cost of Production	$2		

Sources: (Dagwa, 2006; Aderiye, 2012; Amaren, 2010.

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