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Investigation on the Mechanical Properties of Pellets Produced using the Itakpe and Agbaja Iron Ore as Blends

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Abstract The properties investigated include the drop number test from a height of 60 cm, drop resistance test from various heights like 48cm, 60cm and 72cm, the green and dry compressive strength tests and the indurating compressive strength. Other important mechanical properties determined are the moisture content, micro- porosity, tumbler index value and abrasion index value. The investigation showed that the drop number determined gave a value of 3.89cm, while the corresponding ratio was at 70/30 Itakpe / Agbaja blend proportion ratio. At 50/50 the best drop resistance value gave a value at 4.77cm. At 75/25, the blend ratio gave a value of 10.97 N/P indicating the best green compressive strength. The Itakpe / Agbaja blend ratio of 70/30 gave optimum indurating compressive strength of 2592.40N/P which indicates that this ratio is the best suitable for the reduction and production of liquid pig iron in the Blast Furnace and Direct Reduced Iron processes. This result further connotes that the sufficient mechanical strength for produced and fired pellets for 70/30 Itakpe / Agbaja blend ratio. At 50/50 the best moisture content value was 6.76ml. The tumbler index value was 98.82% while the corresponding blend ratio value was at 40/ 60. The best abrasion index value at 55/45 blend ratio for Itakpe / Agbaja iron ore, was 5.14. The micro-porosity value was of the blends at 10/90 was 10.56%.

Keywords Investigation, Mechanical, Properties, ironores, Blends

Introduction

The present material civilization has been largely due to man's knowledge and application of metals. Without metals, there would be no railways, airplanes, automobiles, ships, turbines, electric motors and generally no electrical power. There will be no modern bridges or massive oil rigs and the little but important things of life from simple razor blades to knives and forks and the printed newspaper would be essentially lacking, perhaps, a few of these could be fashioned from wood, but they couldn't go very far. It is also widely recognized that central to all these metallic inventions, innovations and motive power, is the particular class of metal known as "STEEL" [1].

The discovery of Iron ore deposit in Nigeria dated as far back as 1904. The deposits are hematite, magnetite, goethite or siderite – goethite grades. The reserve is estimated at over 3 billion metric tons and their utilization deposits in iron and steel plants will reduce the cost of importation thereby saving foreign exchange, improve Nigerian's technology transfer i.e. agriculture, military defense and provide employment and revenue generation [2].

The Itakpe iron ore deposit is located northeast of Okene in the eastern part of Kogi state, which is presently the most elaborately investigated ferrous deposit in Nigeria. This is been developed for utilization in the Blast Furnace at Ajaokuta Steel Company Limited situated at Ajaokuta Steel township and for steel production operation at the Delta Steel Company, Aladja situated in Delta state for the production of Direct Reduced Iron (DRI).

The topography of the region is a plateau rising gently to the east, down to the river Niger. The plateau is scattered hills that are made of Precambrian gneisses and granites that overlook the surrounding by about 200m to 300m. The Itakpe deposits is part of these hills. Its estimated reserve is over 300 million tons while its proven reserve is 200 million tones [2].

Mineralogical studies of Itakpe deposits, which has been well, documented in the last few years, yield the following features:

Magnetite – hematite quartzite; 19.7%

Hematite - magnétite quartzite; 37.5%

Hematite quartzite; 25.9%

In these various forms, the average chemical or instrumental assay of vital elements or compounds indicates 36.8%Fe, 42.6%SiO_2, 1.0% Al_2O_3 and 0.05% P and 0.05% S. The Fe grade is low to be used in either the blast furnace, which requires about 60-62% Fe grade while the Direct Reduced Iron (DRI) requires about 65-68%Fe grade. The Itakpe iron ore has tolerable percentage of both Sulphur and phosphorous in iron and steel making. The percentage acid gangue should be less than 3.5 % [2]. In this iron ore deposit, materials deleterious to iron and steel production (such as Sulphur, phosphorous and nonferrous metals) are absent from the mineral matrix. The particle size of the constituent iron minerals varies from coarse and fine grained, (with total liberation from gangue at 600µm to 800µm which renders them suitable for conventional beneficiation techniques (like gravity and magnetic separation), unlike the extremely fine grained Agbaja deposits of <5µm liberation size which respond poorly to these processing method [3].

Mineralogy of Agbaja iron ore is Oolithic too in nature, limonite that occurs in mammilated or stalactite forms having fibrous structure resembling hematite [4].

The Iron ore is typically classified as high grade (+65% Fe), medium grade (+62 – 65% Fe) and low grade (-62% Fe). Typically, the Integrated Steel Plants (ISPs) use medium/high grade iron ore whereas the sponge iron plants require only high grade iron ore, preferably, with +67% Fe.

The iron ore obtained from the Agbaja iron ore deposits are in lumps sizes or in fines.

Production/availability of lumps is limited by virtue of the natural occurrence and because of generation of lot of fines during crushing of large lumps present in the run-off –mines (ROM). Natural pellet is a term coined by producers in some Asian counties, to designate sized iron ore used directly in Sponge Iron production. The naturally occurring, extremely friable and high-grade hematite iron ore powder is known as blue dust

The metallurgical plants cannot make use of very low-grade iron ore. The ore needs to upgrade to increase the iron content and reduce the gangue content. Beneficiation process adopted in upgrading the Iron ore to higher iron content through concentration. Iron ore is being beneficiated all round the world to meet the quality requirement of Iron and Steel industries. However, each source of iron ore has its own peculiar mineralogical characteristics and requires the specific beneficiation and metallurgical treatment to get the best product out of it. The choice of the beneficiation treatment depends on the nature of the gangue present and its association with the ore structure. The quality of the iron ores content can be enhanced using several techniques such as washing, jigging, magnetic separation; advanced gravity separation and flotation.

Due to the high density of hematite relative to silicates, beneficiation usually involves a combination of crushing and milling as well as heavy liquid separation. The finely crushed iron ores passes over a bath of solution containing bentonite or other agent, which increases the density of the solution. The hematite can only sink when the density of the solution through calibration. The silicate mineral fragments in the solution can be removed through floating process.

The palletization process generate the formation of ore filtercakes for steel making process. Also during the processing of high grade iron ores which does not need beneficiated, fines which are generated can be pelletized and used instead of been disposed of iron ore pellets formed from beneficiated or run off mine iron fines. The iron ore is ground to a very fine level and mixed with limestone or dolomite as a fluxing agent and bentonite or organic binders as a binding agent. Coke or anthracite coal serves as internal fuel to help fire the pellets, if the ore is a hematite one.

This mixture is blend together in a mixer and fed to balling discs or drums to produce green pellets of size typically about 9-16mm. The induration machine is a vessel where the produced green pellets heated to the required temperature. Both straight grates and grate kilns dry the pellets out in a drying section, then bring the pellets up to a temperature of about 800-900 °C in a preheat zone, then finish the induration process at roughly 1200-1350°C. The pellets cool to a suitable temperature for transporting to a load out facility. Both processes recycle the heat from the pellet back through the process to aid in energy efficiency and decrease fuel usage.

Both processes generate almost any type of desired pellet chemistry, from direct reduction pellets (DR pellets) to Blast Furnace pellets.

Pellets are balls formed by rolling moist concentrates and fines iron ores of different mineralogical and chemical compositions, with the addition of additives and binder, in a horizontal drum or in an inclined disc [5].

Pellets produced in iron making processes must have characteristics that meet the list of quality specifications regarding physical, chemical, and metallurgical properties. Aiming to achieve those specifications, binders and additives in the pelletizing process. Additives such as limestone, dolomite, and hydrated lime are to modify the chemical composition of the pellets, most often for correction of the basicity. Certain substances such as hydrated lime serve as both additive and binder. Fines of anthracite or coke are also added during the pelletizing process for reducing the consumption of fuel required for internally heating the ball [6]. During firing water evaporates from the ball, while the binders gives the pellets sufficient strength to withstand the heating from room temperature to elevated temperature between 1200^{o}C-1350^{o}C at which the pellets harden by sintering [7].

By adjusting the amount of fluxing agent or limestone added, pellets can be made that are anywhere from acid (or non-fluxed) pellets to heavily fluxed pellets. In view of these Nigeria has abundant iron ore deposits located in some state of the Federation like, Kogi, Enugu and Abuja etc. It should be noted that Iron ore deposit was discovered in Nigeria as far back as 1904 since then several deposits have been discovered. Table 1 shows the Chemical Composition and Estimated Reserve of some Nigerian Iron ores. The deposits are hematite, magnetite, goethite or siderite – goethite grades. Effective harnessing of the estimated reserve deposits which runs to over 3.1 billion metric will generate employment opportunities, wealth creation , revenue generation and foreign exchange earnings as these will further improve technological base i.e. in agricultural sector, military defense and provision of infrastructures and reviving of the moribund iron and steel industries across the nation. The pellets produced are to be used in the operation of the Blast furnace and Direct Reduced Iron (DRI) typical example of such furnaces are located at Ajaokuta Steel Company Limited , Ajaokuta Kogi State ,while the other type of furnace is used at the Delta Steel Company Limited , Aldaja , Delta State.

Table 1.1: Chemical Composition and Estimated Reserve of some Nigerian Iron ore

Iron ore Deposit	**Parameters (%)**									**Indicated interred Reserve in MT**
	Fe	**SiO_2**	**Al_2O_3**	**CaO**	**MgO**	**TiO_2**	**MnO**	**P**	**S**	
Itakpe	32.68	44.80	1.0	0.30	0.20	0.10	0.05	0.18	0.05	200$^+$ 310
Oshokoshoko	34.45	51.07	9.67	0.15	0.18	0.61	0.08	0.02	0.007	1085
Ajabanoko	37.22	46.50	3.39	0.21	0.15	-	0.01	0.10	0.03	2565
Agbaja	47.80	10.89	9.60	0.72	0.38	0.37	0.14	0.08	0.12	9621250
KotonKarfi	48.15	5.13	6.70	0.45	0.07	0.24	0.56	2.14	0.04	428,850
BassaNge	46.90	8.28	10.87	0.46	0.46	0.26	0.13	1.45	0.05	825 450
Muro	31.60	40.00	0.40	0.50	2.10	0.20	0.10	0.10	0.10	3.8

Source: Asuquo and Nebo, 1994, Uwadiale and Nwoke, 1995

2.1. Materials

2.1.1. Itakpe Iron Ore

The topography of the region is a plateau rising gently to the north –east of Okene in the eastern part of Kogi State, down to the river Niger. The plateau deposit is scattered with hills that are made of Precambrian gneisses and granites that overlook the surrounding by about 200m to 300m [2]. The Itakpe iron ore deposits is part of these hills. Its estimated reserve is over 300million tons;its proven reserve is 200 million tons [2]. The deposit has an iron ore content of 36%. This has to be beneficiated at rate of 8 million tons per year to produce 64% Fe concentrate as sinter materials, for the Ajaokuta Steel Company Limited Blast furnace and 60% Fe concentrate as pellet feed for the Direct Reduction Plant (DRP) at the Delta Steel Company Limited, Aldaja, Delta State. The iron ore is suitable as a feedstock to one of the Direct Reduction Methods of Iron making. The ore is typical of one formed by magnetic segregation. This iron ore deposit is the most elaborately investigated ferrous deposit in Nigeria, developed for the utilization in the blast furnace. The picture below shows the sample of the Itakpe Iron ore sourced at the National Iron Ore Mining Company (NIOMCO) Itakpe, Kogi State, Nigeria. The Itakpe iron ore specimen is known to be a compacted, crystalline like banded iron ore which has various colours like dark grey, brown and black. The Itakpe iron ore slightly magnetic in nature.

Figure 2.1: The sourced Itakpe Iron ore (NIOMCO)

2.1.2. Agbaja Iron Ores

The Agbaja Iron ore is an acidic pisolitic/ oolitic ore consisting of goethite, magnetic and major amounts of aluminous and siliceous materials [4]. It cannot be used directly in the Blast Furnace process or other reduction process without further treatment e.g. palletization or briquetting. The ore is a lean ore and sedimentary origin (BRG Report, 1983). It is therefore necessary to harness the opportunities created to work upon the ore in order to add economic value to our national economy. The ore is also known to be oolittitic in nature, limonite that occur in mannmilated or stalactite forms having fibrous structure resembling hematite [4]. The Agbaja Iron ore are made of brown compacted fine-grained materials, which consist of extremely lager particles, which show the tendency to be friable. Agbaja iron ore is strongly magnetic [5]. The ore particles processed by crushing them for specific experimental procedure. The Agbaja iron ore sample is compacted ground fine particles, which significantly exhibits the characteristics of being friable and magnetically strong. The picture below shows the iron ore sourced at the Agbaja plateau in Kogi State.

Figure 2.2: The sourced Agbaja iron ore

2.2. Equipment and Methods

The equipment used for the preparation of the two ores samples. Some of the experiments carried out at the National Metallurgical Development Centre (NMDC), Jos Plateau State. Other experiments performed at the Laboratories in the Department of Metallurgical and Materials Engineering and Laboratories at the Nigerian Liquefied Natural Gas (NLNG), University of Nigeria (UNN), Nsukka, Enugu State and the Laboratories of

Extractive Metallurgy at Tshwane University of Technology, South Africa.

(a) Ball Milling Machine: The Ball Milling Machine was used to crush and ground the samples at the National Metallurgical Development Centre, (NMDC) Jos were a Ball milling machine made by Bico Sprecher and Schn (2287) were used. The samples were further prepared by using sieve sizes of 0.5mm and 0.63mm respectively for the screening of the iron ore sizes to international standard.

(b) Pelletizing Machine: The production of pellets were performed with the use of Pelletizing machine with model name Form and Test Seidner Strength testing machine ,while an equipment with model name D7940, Salter Scale 50kg type was used for the weighing of the milled iron ore.

(c) Electronic Digital Weighing Balance: The Electronic Digital Weighing Balance with model name C&G GmbH Gielerister 65-69 (41460) Neuss, Germany was used for weighing of the produced pellets at the laboratory of the Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka.

(d) Beaker: Some beakers filled with Benzene for the determination of the Micro porosity value after the iron ore samples heated to 900^{o}C.

(e) Sample handler: The produced pellets were carefully handled with a view to handling them properly without breakage.

(f) Muffle furnace: A Muffle furnace was employed for the heating of the produced pellets and the iron ores lumps. The pellets heated for determining the indurating compressive strength and Micro porosity value before immersing the samples into benzene solution.

(g) The Laboratory Dry Oven: The Laboratory Dry Oven with model number DHG 9101 for heating of the pellets at low temperature particularly with respect to determining the moisture contents of all the produced pellets [8].

(h) Testometric Testing Machine: Testing of samples were carried with the use of the Testometric Testing Machine with model name M500-250CT manufactured by a British company. Indurating Compressive Strength, Green and Dry compressive strength Machine located at the laboratory of the Department of Metallurgical and Materials Engineering situated at the Nigerian Liquefied Natural Gas (NLNG) building.

2.3. Methods

As stated, earlier the mechanical characteristics of blended iron ore pellets investigated to evaluate the possibility of using the blend mixture to produce liquid pig iron in the blast furnace. The Drop number, Drop resistance, Green compression strength, Dry compression strength and Indurating compressive strength values, Micro porosity, the tumbler index values and the abrasion index values used as major criteria in assessing the selected blends under study. The results of the mechanical properties of the blended Itakpe / Agbaja iron ores.

2.4. Mechanical Properties of Pellets Produced Using the Itakpe and Agbaja Iron Ore Blends

The experimental materials used for the investigating the iron ore lumps obtained from the mine site in Itakpe a town close to Okene, while the other ore was obtained from the Agbaja plateau in Agbaja town in Oworo Local Government Area , both in Kogi State Nigeria. The chemical compositions of the ores were determined using the X-Ray Fluorescence (XRF), which showed the compositions of the ores, while the X-Ray Diffraction (XRD) used to determine the nature of the ores. The investigation of the mechanical properties of both ores were properly observed and standard procedures were used as the parameters for comparing the results obtained [8].

2.4.1. Sample Preparation (Pellet Preparation)

15 kg of each iron ore of Itakpe and Agbaja charged at different times into ball milling machine made by Bico Sprecher and Schn (2287) Industrial control, United State of America. Then one Thousand six hundred balls of varying diameters ranging from 15 mm to 40 mm were charged into the ball mill (15 mm balls – 320 pieces, 20mm balls-320 pieces, 25mm balls-320 pieces , 30 mm balls -320 pieces and 40mm-320 pieces).

The samples were allowed to mill for six (6) hours after which they were discharged and sieved using 0.63mm sieve size. The oversize materials were recycled until they all passed through the 0.63mm sieve. At this point, the samples prepared are:

1.15 kg Itakpe iron ore pulverized to – 0.63 mm sieve size

2. 15kg Agbaja iron ore pulverized to – 0.63mm sieve size.

Figure 2.3: The crushed Itakpe

Figure 2.4: The crushed Agbaja

1500g blended Iron ore weighed with Itakpe iron ore in the blend-1425g. (95%) and Agbaja iron ore in the blend-75g.(5%) were weighed using Salter Digital weighing balance with trade mark – Mettler Pm 2000.The weighed samples were charged into a clean and moisture free Erich 2287 Palletizing disc machine of 35cm diameter wide palletizing disc. 4% lime was also added, while the Machine rotated at the speed of 25 rpm. The samples were properly mixed after which 1000 mls of water by volume was measured and added to the iron ore mix in the rotating pelletizing disc which work gradually; while the charge were been scrapped on a continuous basis to avoid sticking to the disc. As the experiment progresses the pellets of varying diameters ranging from 10mm to 20mm formed. Rotation of the Pelletizing disc continued in a reduced speed of 15rpm; after satisfactory formation of pellets impacted further strength on the pellets formed.

Figure 2.5: The pulverized Itakpe iron ore

Figure 2.6: The pulverized Agbaja Iron ore

Figure 2.7 : Some produced pellets from Itakpe Iron Ore

Figure 2.8: Some produced pellets from Agbaja Iron ore

2.6.2. Drop Number Test of Pellets from Height of 60cm

The process of drop number test of pellets performed by selecting eight (8) green pellets randomly from each group of blends produced. The selected eight (8) samples from each of the group dropped from a measured height of 60cm where the results of the number of drop numbers observed until the samples fell and fractured into pieces. The number of failure progressed continuously until fracture attained and the obtained results values recorded as the drop number. The process were performed for other selected pellet samples where the average values of the best six(6) pellets sample results were taken and recorded as the drop number for that particular set of blend.

2.6.3. Drop Resistance test of pellets from 48cm, 60cm and 72cm height

The drop resistance test of the pellets from 48cm, 60cm and 72cm height performed. Eight (8) green pellets samples from each group of blends produced selected randomly. Eight samples dropped for the drop resistance test as measured from a measured height of 48cm, 60cm and 72-cm. Efforts were made to see that the number of drop resistance continued until the samples fell and fractured into pieces. The number of failures were observed until the samples were fractured into piece and thereafter the drop resistance values obtained were recorded after the samples were placed under load on the testing machine Note that all the eight(8) selected samples were tested but the best six(6) samples test for the drop resistance results were taken. Average values of the drop resistance test of the samples reading gave the actual drop resistance test of the pellets.

2.6.4. Green compressive strength test

The Testometric testing Machine with M500-25CT a Laboratory Test equipment British model located at the Nigerian Liquefied Natural Gas (NLNG), at the Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka used to perform the Green Compressive Strength test. The eight (8) samples randomly selected from each group of the produced pellets, which subjected to load until scattered occurred. The readings of the scattered load observed as the samples placed under the testing machine. The results of the best six pellets samples taken and recorded and the average value of the readings taken gave actual green compressive strength results. Same experimental procedures repeated for the rest of the pellets.

2.6.5. Dry compressive strength test

The Dry compressive strength tests were carried out after the samples were randomly selected from each of the group of blend sample prepared this indicates that 95% Itakpe iron ore and 5% Agbaja iron ore were fired in muffle furnace to 600^{o}C. After which they were subjected to load test by using the Testometric testing machine with M500-25CT the readings of the scattered load tests were observed as the samples were placed under the testing machine until fracture were observed and values obtained were recorded. The results of the best six pellets samples taken and recorded. The average values of the compressed sample readings gave the actual dry compressive strength tests of the pellets. Same procedures applied to the rest of the pellets.

2.6.6. Indurating compressive strength test

The indurating compressive strength tests experiment were performed and observed where eight (8) samples of pellets were randomly selected and subjected to heating processes. The experiments carried out using the muffle furnace at the Foundry Section in the Department of the Metallurgical and Materials Engineering, University of Nigeria, Nsukka. The only difference was that pellets tested in the group the samples fired in a heating furnace to a temperature of 1200^{o}C for one hour, before the samples subjected to load using the Testometric testing machine with M500-25CT.

The readings of the scattered load were observed as the samples were placed under the testing machine until fracture were observed and the obtained values were recorded and the average of the readings of the best six samples results were taken as the actual indurating compressive strength test of the pellets. The same experimental procedures repeated to the rest of the blends

2.6.7. Moisture Content of Pellet in Each Blend

Eight (8) pellet samples randomly selected from a set of group of blended pellets produced. The samples weighed using a digital weighing balance of model Electronic Scale –C & G GMbH Gielensto 65-69 41460 Neuss, Germany, at the Nigerian Liquefied Natural Gas (NLNG), at the Faculty of Engineering, University of

Nigeria, and Nsukka. The moisture content of the samples performed as they serves as a representative of the pellets of a blend taken and placed in to a crucible. The samples weighed with the same weighing scale and the readings carefully recorded the crucible and pellets then transferred into a heating oven with model DHG-9101 Laboratory Dry Oven. The experiments took place at the Nigerian Liquefied Natural Gas (NLNG). The sample heated to a temperature at 105^{o}C this process continued for two (2) hours and broughtout from the oven and, weighed,and allowed to cool down. The samples taken back into the heating oven and then reheated for another one (1) hour, thereafter the samples cool down and re- weighed; this process took place severally until other results readings took place.

Weight of initial crucible + the sample = W_1

Weight of final crucible + the sample = W_2

Volume of H_2O expelled from sample = W_1- W_2

2.6.8. Micro-Porosity of Pellet in Each Blend

The Micro-Porosity of the pellets were performed, the weighted pellets were to 900^{o}C using the muffle furnace, with model number LABE 1210, Divine International, Delhi. The samples were removed from the furnace, and dropped into a beaker containing benzene. Immediatelybubblesemanated from the pellets, which indicate that empty spaces in the pellets filled with benzene displacing the blow of air filled with benzene. The displacing the blow of air within the pellets, which was caused by the firing of the pellets. The samples remained in benzene solution until the bubbles stopped. The pellets were taken out from the benzene solution and quickly weighed. These processes continued repeatedly for all other samples from other blends.

$$\%\,Porosity = \frac{Wt\ of\ Pellets\ in\ Benzene\ (D) - Wt\ of\ Pellets\ before\ immersion\ in\ Benzene\ (d)}{Wt\ of\ Pellets\ in\ Benzene\ (D)}$$

$$= \frac{\mathrm{D - d}}{\mathrm{D}} x100\%$$

2.6.9. Tumbler Resistance Test

The tumbler resistance tests performed where 60 Pellets of 95% Itakpe Iron ore and 5% Agbaja iron ore blend taken and weighed at 600gms. The samples were fired and dried at 150 ºC slowly in a heating furnace for two (2) hours. Then the pellets were introduced into a drum with diameter 0.25m, length 0.1m, with two (2) lifters each of height 0.25m located inside the drum which was allowed to rotate for six (6) minutes at a speed of 24rpm, after which the chattered pellets were screened and the fraction of +0.63mm . The percentage of separated fractions in proportion to the feed weight was the value of tumbler index (i.e. +0.63)

$$Tumbler\ index\ value = \frac{Wt\ of\ Chattered\ Pellets\ at - 6.3\ mm}{Total\ wt\ of\ Pellets\ charged}$$

2.6.10. Abrasion Index value

The abrasion tests carried out using 60 pellets samples of 95% Itakpe Iron ore and 5% Agbaja iron ore blend weighing 600gms. The sample of the pellets were fired and dried at 150 ºC slowly in a heating furnace for two (2) hours. The samples were then removed from the furnace and placed into a drum with diameter 0.25m, length 0.1m, with two (2) lifters each of height 0.25m located inside the drum which was allowed to rotate for six (6) minutes at a speed of 24rpm, after which the chattered pellets were screened and the fraction -0.5mm. The percentage of separated fractions in proportion to the feed weight was the value of abrasion index (i.e. - 0.5mm).

$$Abrasion\ index\ value = \frac{Wt\ of\ Chattered\ Pellets\ at - 0.5\ mm}{Total\ wt\ of\ Pellets\ charged}$$

2.8. Scanning Electron Microscope (SEM)

2.8.1. Scanning Electron Microscope (SEM)of Itakpe Iron Ore

Examination by Scanning Electron Microscopy (SEM) /Energy-Dispersive Spectroscopy (EDS) shows that there are grey phase was quartz, the white phase hematite, and the mottled areas intergrowths of hematite and magnetite.

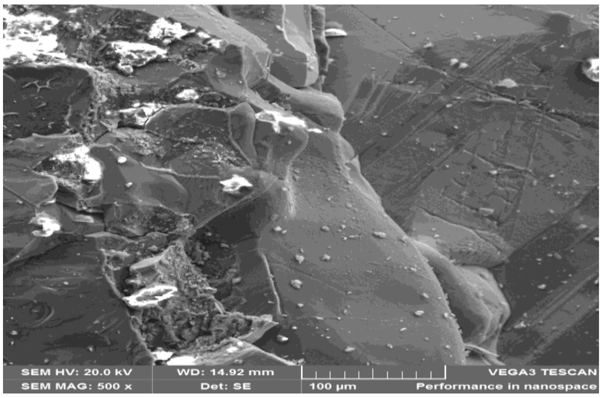

Figure 2.9: The scanning electron Microscopy SEM of the Itakpe Iron ore at 100µm

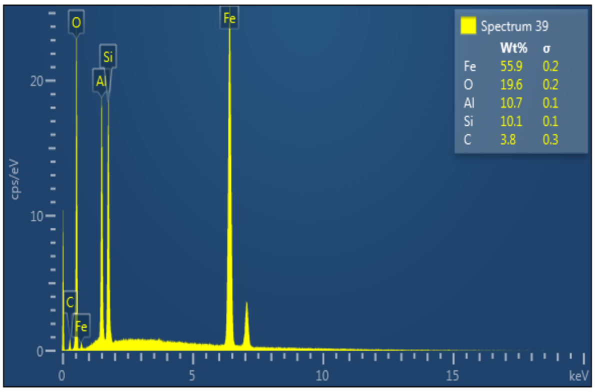

Figure 2.10: Energy-Dispersive Analysis of the Itakpe Iron ore

2.8.2. Scanning Electron Microscope (SEM)of Agbaja Iron Ore

Examination by Scanning Electron Microscopy (SEM) /Energy-Dispersive Spectroscopy (EDS) shows that there are fine and whitish structures.

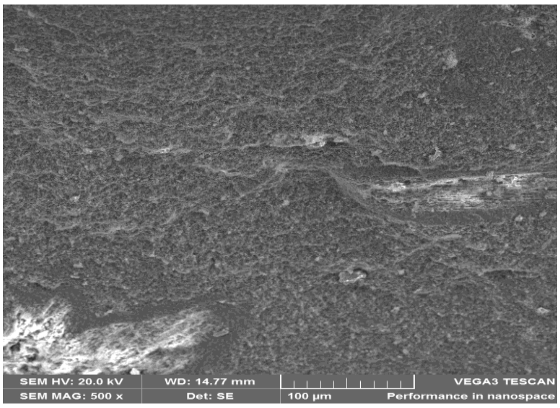

Figure 2.11: The scanning electron microscopy of Agbaja Iron Ore at 100µm

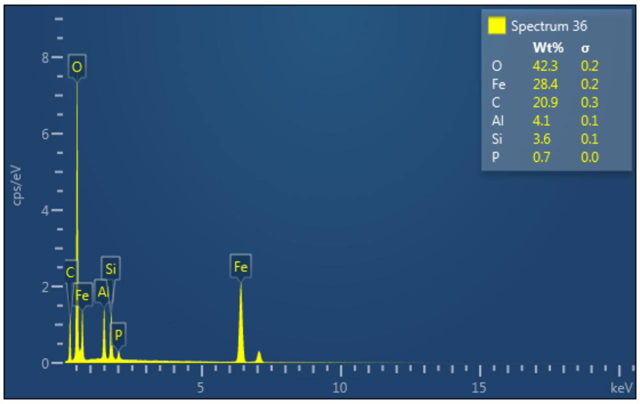

Figure 2.12: Energy-Dispersive of the Agbaja Iron ore

3.1. Mechanical Properties of Produced Pellets using Itakpe and Agbaja Iron Ore Blends

The mechanical properties of the blended iron ore pellets produced investigated to evaluate the possibility of using the blend mixture to produce liquid pig iron in the blast furnace and in the Direct Reduced Iron (DRI) process. The mechanical properties investigated are: Drop Number (DN), Drop Resistance (DR), Green Compression Strength Test (GCST), Dry Compression Strength Test (DCST), Indurating Compressive Strength Values (ICSV), Moisture Content (MC), Tumbler Index Value (TIV) and the Abrasion Index value (AIV). These constituents the major criteria in investigation of the samples selected of blends as being performed in this research work. The details of the result could be found on figures (3.1-3.10).

3.1.1. Drop Number

Figure 3.1 indicates the variation of drop number ranging from 100 percentage of Itakpe Iron ore with an interval variation of 5 percentage until it 100 percentage of Agbaja Iron ore was obtained. From the graph obtained it shows that the highest value of the drop number at exactly at 3.89 cm. The corresponding ratio at which this was attained was at 70/30 Itakpe/Agbaja blend proportion ratio.

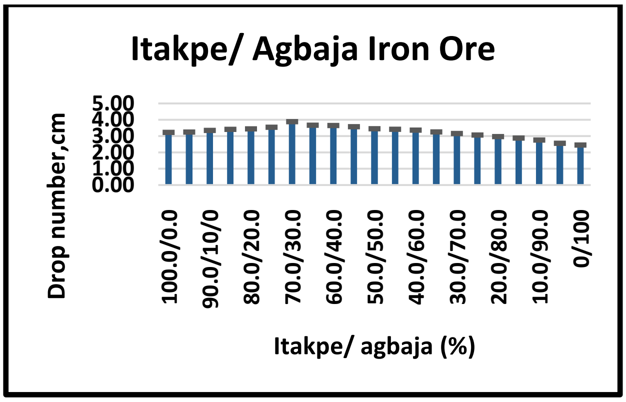

Figure 3.1: variation of drop number with various blends of Intake/Abuja Iron Ore Pellets

3.1.2. Drop Resistance

Figure 3.2 indicates the variation of drop resistance value ranging from 100 percentage of Itakpe iron ore with an interval variation of 5 percentage until it 100 percentage of Agbaja iron ore was obtained. From the graph, it shows that the best values of the drop resistance point of Itakpe/Agbaja blend ratio at 50/50 with a corresponding value of 4.77cm.

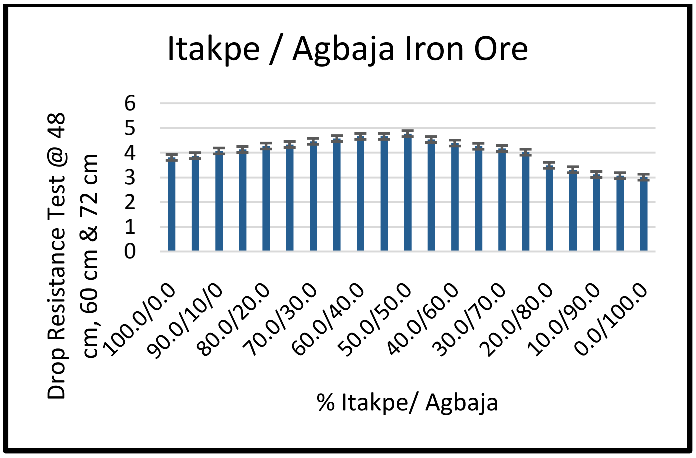

Figure 3.2: Variation of Drop Resistance with various blends of Itakpe/ Agbaja Iron Ore Pellets

3.1.3. Green Compression

Figure 3.3 shows variation of Green Compressive Strength with various blends of Itakpe / Agbaja Iron Ore Pellets. The best green compression strength amongst the blend mixtures at 75/25 blend ratio of Itakpe/Agbaja with a value of 10.97N/P.

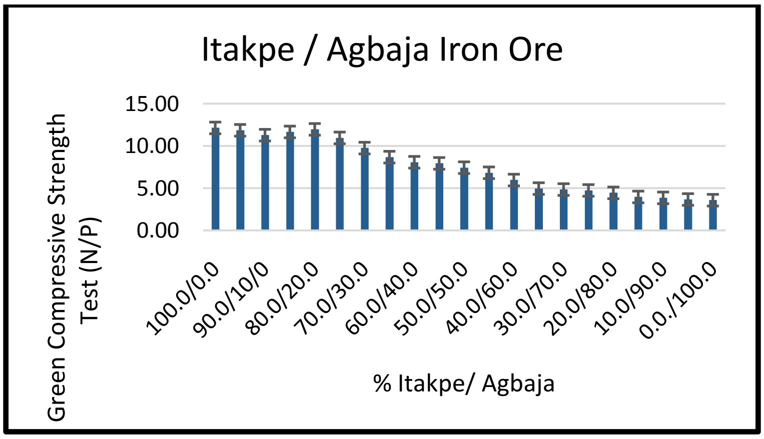

Figure 3.3: Variation of Green Compressive Strength with various blends of Itakpe/Agbaja Iron Ore Pellets

3.1.4. Dry Compression

Figure 3.4 indicates variation of Dry Compressive Strength with various blends of Itakpe/Agbaja iron ore pellets. In this trend the best green compression strength amongst the blend mixtures at 75/25 Itakpe/Agbaja, blend ratio with green compressive strength of 33.86N/P.

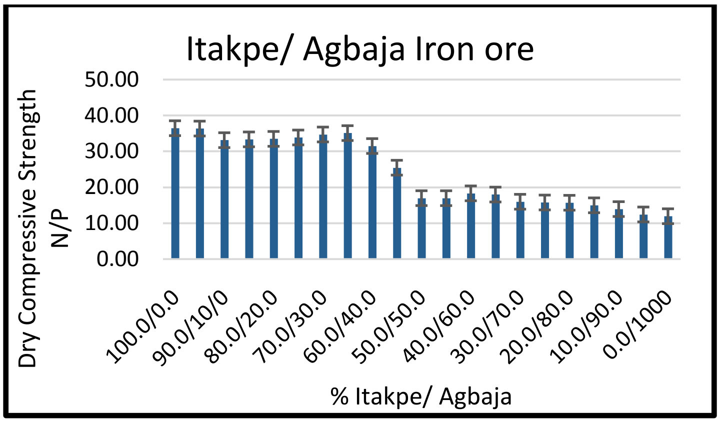

Figure 3.4: Variation of Dry Compressive Strength with Various blends of Itakpe/Agbaja Iron Ore Pellets

3.1.4. Indurating Compressive Strength Test

Figure 3.5 shows variation of Indurating Compressive Strength with various blends of Itakpe/Agbaja iron ore pellets. In this trend the best Indurating compressive strength amongst the blend mixtures at 70/30 Itakpe/Agbaja, blend ratio with indurating compressive strength of 2592.40N/P.

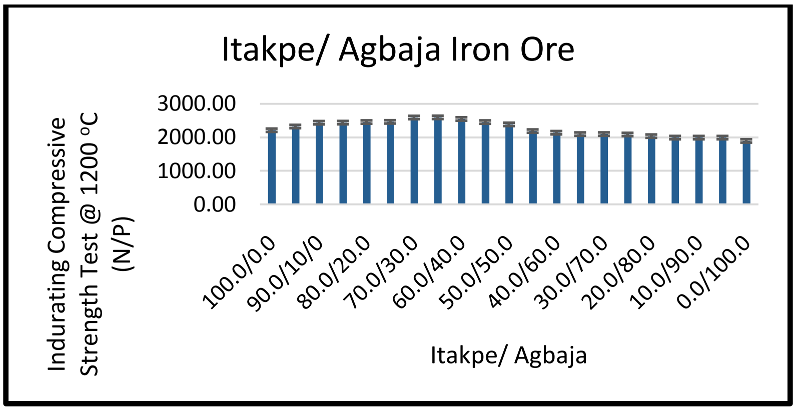

Figure 3.5: Variation of Indurating Compressive Strength with various blends of Itakpe/Agbaja Iron Ore Pellets

3.1.5. Moisture Content

Figure 3.6 shows variation of moisture content with various blends of Itakpe/Agbaja iron ore pellets Itakpe/Agbaja blend ratios of 50/50 has moisture content value of 6.76ml.

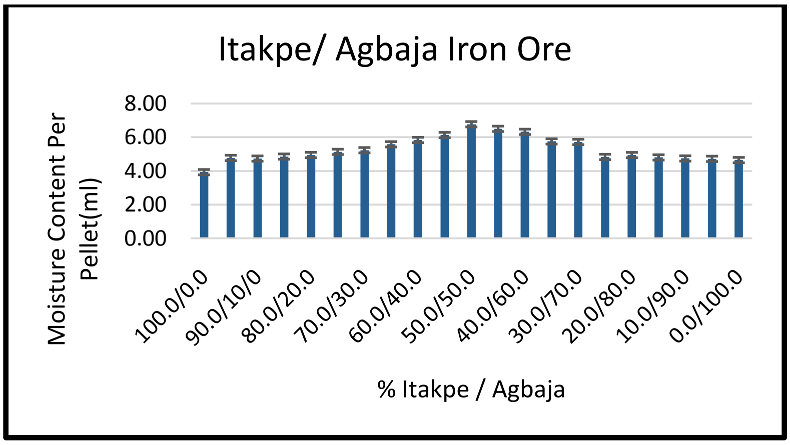

Figure 3.6: Variation of Moisture Content with Various blends of Itakpe/Agbaja Iron Ore Pellets

3.1.6. Tumbler Index Value: Figure 3.7 shows variation of tumbler index with various blends of Itakpe/Agbaja iron ore pellets. Itakpe/Agbaja blend ratio of 40/60 has tumbler index value of 93.82 percent

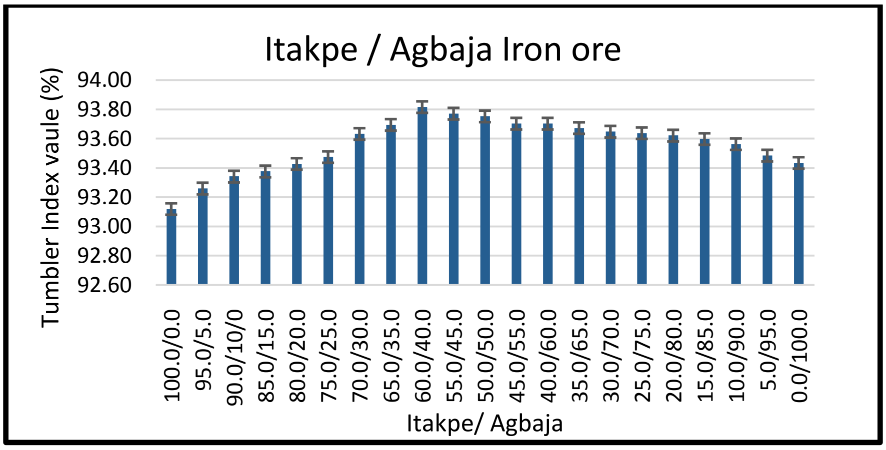

Figure 3.7: Variation of Tumbler Index with various blends of Itakpe/Agbaja Iron Ore Pellets

3.1.7. Abrasion Index Value

Figure 3.8 shows variation of abrasion index with various blends of Itakpe/Agbaja iron ore pellet. Itakpe/Agbaja blend ratio of 55/45 gave abrasion index value of 5.14 percent.

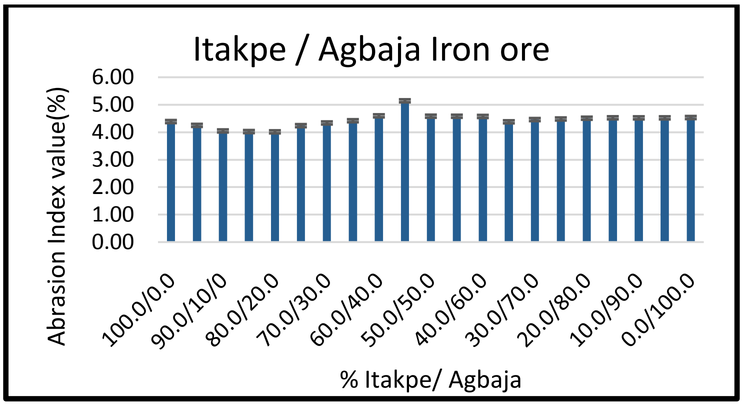

Figure 3.8: Variation of Abrasion Index with various blends of Itakpe/Agbaja Iron Ore Pellet

3.1.8. Micro-Porosity

Figure 3.9 shows the best micro-porosity point at Itakpe/Agbaja blend ratio of 10/90 with a value of 10.56 percent. According to experiment this velocity is always so high that even porosity variation between 10-30% hardly cause great differences and the major part of pellets qualities is within the upper limit of this range.

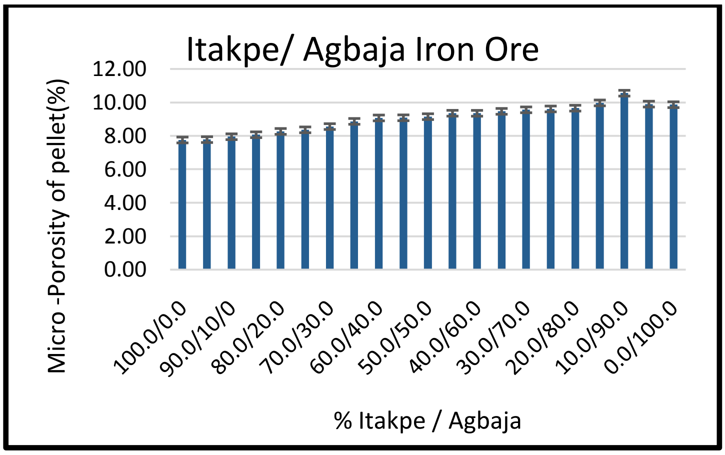

Figure 3.9: Variation of Micro-Porosity with various blends of Itakpe/Agbaja Iron ore Pellet

Table 3.1: Mechanical Properties of blended Itakpe and Agbaja Iron ore

S/NO	Drop number	Drop Resi.	Green Compr.	Dry Compr.	Indurating Index	Mositure Content	Tumbler Index value	Abrasive Index	Micro Porosity
100/0.00	3.23	3.81	12.14	36.4	2212.42	3.93	93.12	4.39	7.73
95/5.00	3.25	3.88	11.86	36.3	2323.64	4.86	93.26	4.25	7.76
90/10.00	3.35	4.07	11.29	33.1	2436.35	4.74	93.34	4.05	7.78
85/15.00	3.42	4.13	11.67	33.3	2439.51	4.86	93.37	4.02	7.95
80/20.00	3.45	4.27	11.98	33.5	2456.7	4.97	93.43	4.01	8.07
75/25.00	3.55	4.33	10.97	33.9	2461.53	5.14	93.48	4.24	8.27
70/30.00	3.89	4.47	9.76	34.7	2592.4	5.23	93.63	4.34	8.37
65/35.00	3.67	4.57	9.69	35.1	2596.3	5.58	93.7	4.42	8.56
60/40.00	3.65	4.68	9.48	31.5	2547.72	5.84	93.83	4.59	8.87
55/45.00	3.57	4.67	9.42	25.4	2455.28	6.13	93.77	5.14	9.08
50/50.00	3.46	4.78	9.33	17	2387.08	6.77	93.75	4.58	9.09
45/55.00	3.42	4.49	9.02	16.9	2186.18	6.5	93.74	4.58	9.15
40/60.00	3.37	4.36	8.93	18.3	2138.1	6.32	93.7	4.57	9.36
35/65.00	3.26	4.23	8.64	18	2097.09	5.73	93.67	4.38	9.36
30/70.00	3.17	4.17	8.57	16	2097.49	5.72	93.65	4.47	9.47
25/75.00	3.07	4.02	8.47	15.7	2085.89	4.83	93.64	4.48	9.56
20/80.00	2.97	3.47	8.87	15.7	2035.78	4.95	93.62	4.52	9.62
15/85.00	2.88	3.33	9.32	15	1992.67	4.81	93.6	4.52	9.66
10/90.00	2.77	3.12	9.37	13.9	1992.33	4.75	93.56	4.52	9.98
5/95.00	2.57	3.08	9.48	12.4	1992.15	4.72	93.49	4.52	10.56
0/100.00	2.46	3.01	9.59	11.9	1892.57	4.65	93.44	4.53	9.9

4. Conclusions

The study on the mechanical properties of produced pellets using Itakpe and Agbaja iron ore blends investigated. The studies carried out reveal the followings:

(a) The mechanical properties determined showed that the sufficient mechanical strength of produced fired pellets for 70/30 blend ratio of Itakpe/ Agbaja iron ore. .

(b) The blend ratio of 70/ 30 of Itakpe / Agbaja iron ore gave optimum indurating compressive strength of 2592.40 N/P and therefore suitable for the reduction and production of liquid pig iron in the Blast Furnace and the Direct Reduced Iron at the Ajaokuta Company Limited and the Delta Company Limited at Aladja respectively .

(c) The green compressive strength value of the produced fired pellets shows that there was presence of hygroscopic and hydrated water.

(d) The findings revealed that the results and data obtained be used for further study while the other iron ore deposits in the country could also be subjected to other experimental investigations and processes. Investigate such ores by determining their mechanical properties.

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