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EVALUATING MECHANICAL PROPERTIES OF IRON ORE PELLETS FROM ITAKPE AND AGBAJA BLENDS

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Abstract: The determination of the mechanical properties of resultant pellets of Itakpe and Agbaja iron ore blends were carried out. The drop number determined gave a value of 3.89cm, at 70/30 Itakpe / Agbaja blend proportion ratio. The best drop resistance for Itakpe /Agbaja iron ore blend ratio at 60/40 with the corresponding value at 4.78cm. The best green compressive strength value at 11.98 N/P with corresponding blend ratio at 80/20 of Itakpe/Agbaja iron ore. The dry compression strength has a value of 34.7N/P with a corresponding blend ratio of 70/30 for Itakpe / Agbaja. 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. These results further connotes that the sufficient mechanical strength for pellets for 70/30 Itakpe / Agbaja blend ratio gave better value. The best moisture content for Itakpe / Agbaja iron ore at 50/50, while the corresponding value was 6.76ml. The tumbler index value for Itakpe / Agbaja iron ore at 93.83% while the corresponding blend ratio value at 60/ 40. The best abrasion index value was obtained at a blend ratio of 60/40 for Itakpe / Agbaja iron ore, while the corresponding value was 4.59%. The microporosity value was achieved at a blend ratio of 10/90 Itakpe/ Agbaja iron ore, while the corresponding value was 9.98%.
Keywords: Determination, Mechanical properties, Resultant Pellets, Blend, Itakpe, Agbaja Iron Ore

Introduction

The Itakpe iron ore deposit is located northeast of Okene in the eastern part of Kogi state. This ore deposit is most widely experimented iron ore in Nigeria. The investigation is gear towards the usage of the ore in the Blast Furnace at Ajaokuta Steel Company Limited, Ajaokuta in Kogi State. The research on this ore is to also utilize it for steel production operation at the Delta Steel Company, Aladja, Delta state. The steel company has a Direct Reduced Iron (DRI) processes which use pellets as one of the raw materials.
The topography of the region is a plateau dovetailing to the east, down to the river Niger. The plateau is made of scattered hills, which are made of Precambrian gneisses and granites that overlook the surrounding by about 200m to 300m. The Itakpe deposits are part of these hills. Its estimated reserve is over 300 million tonnes while its proven reserve is 200 million tonnes.[1]. 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 - magnetite quartzite; 37.5%

Hematite quartzite; 25.9%

In this iron ore deposit, deleterious materials to iron and steel production (such as Sulphur, phosphorous and non-ferrous 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 methods [2].

The Agbaja iron ore deposit is located at Agbaja town which is made up of hills and plateau. Mineralogy of Agbaja iron ore I known to be Oolithic in nature. Limonite occurs in mammilated or stalactite forms having fibrous structure resembling hematite[3].

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 filter cakes are used to produce pellets for steel making processes. Processing of high-grade iron ores does not need to be beneficiated, fines generated from the ores can be pelletized and used instead of been disposed of iron ore pellets formed from beneficiated or run off mine iron fines. The iron ores are ground to a very fine level and mixed with limestone or dolomite as fluxing agent and bentonite or organic binders as a binding agent during the production of pellets. The pellets are fired with mixture contains coke and anthracite coal particularly when the ore is hematite in nature as this serves an internal fuel.

The balling disc or drums are devices used for the production of green pellets of size typically about 9-16mm. blending of the mixtures take place in the mixer. The induration machine is a vessel where the produced green pellets are further processed. 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, The process is then finished by using the induration process at roughly temperatures between 1200-1350°C. The produced pellets are cooled to a suitable temperature for the sake of transporting to a load-out facility. Both processes recycle the heat from the pellets back through the process to aid in energy efficiency and decrease fuel usage. The two processes generate almost any type of desired pellets in chemistry, from direct reduction pellets (DR pellets) to Blast Furnace pellets. By adjusting the amount of fluxing agent or limestone additions, pellets can be made from acid (or non-fluxed) to heavily fluxed pellets. In view of these Nigeria is blessed with abundant iron ore deposits located in some state of the Federation like Kogi, Enugu and Abuja etc.

Palletization

In the modern time of availability of iron ore deposits located in Nigeria, it is very important to use these raw materials that can not only increase the productivity of plant but can also produce better quality iron. Blast furnace raw materials have changed in character greatly in the last three or four decades. Formerly, they used to be raw iron ores, raw limestone and coke. They are increasingly being replaced by pre-fluxed sinter, pellets, liquid and gaseous fuels. Revolutionary changes have been brought to the present day iron-making industries by using pellets as burden materials in the Blast Furnace and Direct Reduced Iron operations.

Pelletization is a process where fine and concentrates are mixed possibly with binder, rolled into balls and fired or indurated until they becomes hard. This process consists of two district operations forming the pellets at atmospheric temperature and firing at an elevated temperature at about 1350^{o}C. The pellets are formed by rolling most fine ores, with the addition of a binder in a rotary disc, drum and cones. Pelletizing is employed in processing ore fines finer than 100 mesh (150µm) which cannot be agglomerated by sintering process, Drum used in large scale production are about 2m in diameter and inclined at 5-100 to the horizontal. It rotates at 15-20 rev/mm. The pellets are rolled normally to a diameter between 10 and 30m. The resultant green pellets have sufficient strength to withstand handling to the firing state. Firing of pellets are also known as induration, this process is carried out on a sintering grate or in a shaft furnace. Firing is brought about using either gas or oil as fuel. During firing water evaporates from the ball, while the binders give the pellets sufficient strength to withstand the heating from room temperature to elevated temperature between 1200ºC-1350ºC at which the pellets harden by sintering. [4].

During mining and ore dressing operations, especially where very fine grinding is necessary for wet concentrations, a large amount of -0.05 mm fines is generated which are not amenable to pelleting because of very low permeability of the bed. They can, however, be agglomerated by balling them up in presence of moisture and suitable additives like bentonite, lime etc. into 8-20 mm or larger size. These green pellets are subsequently hardened for handling and transport by firing or indurating at temperature 1200ºC-1350ºC. The balling stage is the most important part of the process and determines the strength, size compactness and other pellets properties. The operation is performed in rotating devices like drums, discs (with a flange on the rim) and cones, the most used being the former two. The effectiveness of the plain can be increased by fixing daffles inside. The ball formation occurs because of the surface tension of the water forces and collision between particles. Initially, small nuclei of pellets are formed on addition of water and the nuclei grew bigger into balls and then into pellets as the peak of loose grain particles during their travel through the drum which is slightly tilted. The angle of tilt determines the time of residence, pellet size and productivity. The size and shape of the drum should be such as to obtain the most favourable conditions of motion and pressure that is more of rolling as opposed to sliding action.

Pelletizing process and raw materials

The iron ore is mined mostly from open-pit deposits through mining operations and the raw product, "run-off mine," is subjected to mineral processing. Thus, the material is exposed to a series of operations of fragmentation, separation by size, concentration, dewatering, etc., aiming to adequate the chemical, physical, and metallurgical characteristics to meet the demands of iron making processes. The particle size distribution of iron ore is a very important requirement to be characterized after its mineral processing. Materials containing a very fine particle size distribution are not adequate to be used directly in the reduction reactors, requiring to be agglomerated by different processes such as sintering or pelletizing.

The main used reduction reactors are the blast furnace (BF) and direct reduction reactors (DR). In the blast furnace, iron is reduced and melted and the most common product is liquid iron called hot metal. Indirect reduction, iron remains in solid-state and the product is called direct reduced iron (DRI).

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

Pellets produced to be used 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 are used in the pelletizing process. Additives such as limestone, dolomite, and hydrated lime are used 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]. Pellets are obtained by adding an appropriate amount of water to the iron ore concentrate; this is a fundamental factor in the formation and growth of pellets, which creates a surface tension that holds the mineral grains cohesive, thus allowing their handling [7]. This cohesive tension of fine particles due to water is called neutral tension. Neutral tension, however, is not sufficient to keep cohesive grains as dense as iron minerals. Furthermore, when the pellet is heated, the vaporization of water occurs and the pellets tend to disintegrate.

To avoid such effects, binders are added to the material to be pelletized, aiming to: • increase the strength of pellets before heating (green strength); • prevent the collapse of pellets during the initial stages of heating, when a large volume of gas generated by water vaporization tends to crack the pellets. Evenly distributed moisture and binder in the feeding process is decisive to improve the characteristics of pellets, especially to avoid the formation of undesirable agglomerates before the pellet formation. Bentonite is an effective, widely used binder in the iron ore pelletizing process. Its low price is an important factor for its extensive use. However, bentonite incorporates silica and alumina, which are undesirable contaminants to pellets. Additionally, it is a natural material with variable composition depending on its origin. Obtaining a suitable binding effect requires a relatively large amount of material, around 0.5% by weight, which makes handling more difficult and increases logistics costs.

Research Methodology

Materials

Itakpe Iron Ore

The deposit has an average iron ore content of 36%. This has to be beneficiated at a rate of 8 million tonnes 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, and Delta State. The iron ore is suitable as a feedstock to one of the Direct Reduction methods of Ironmaking. The ore is typical of one formed by magnetic segregation. This iron ore deposit is the most elaborately investigated ferrous deposit in Nigeria, which is being 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 1: show the sourced Itakpe Iron ore (NIOMCO)

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 [3]. It cannot be used directly in the Blast Furnace process or other reduction processes without further treatment e.g. pelletization or briquette. The ore is a lean ore and sedimentary origin [3]. It is, therefore, necessary to harness the opportunities created to work on the ore in order to add economic value to the nation’s economy. The Agbaja Iron ore is made of brown compacted fine-grained materials, which consist of extremely lager particles, and friable in nature. Agbaja iron ore is strongly magnetic [8]. The ore particles were further processed by crushing them for specific experimental procedure. The Agbaja iron ore samples are compacted ground fine particles, which significantly exhibits the characteristics of being friable and magnetically strong. The picture below shows the iron ore as being sourced at the Agbaja Plateau in Kogi State.

Figure: 2 Shows the sourced Agbaja iron ore (NMDC)

Mechanical Properties of Resultant Pellets from Itakpe / Agbaja Iron Ore Blends

The experimental materials used for the studies, the iron ore lumps were obtained at the National Iron Ore Mining Company(NIOMCO) site in Itakpe a town close to Okene. The Agbaja iron ore was obtained from the Agbaja Plateau in Oworo both in Kogi State.

Sample Preparation (Pellet Preparation)

15 kg of each iron ore lumps of Itakpe and Agbaja were 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 (1600) 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 balls320 pieces, 30 mm balls -320 pieces and 40mm-320 pieces).

The samples were allowed to mill for seven (7) hours after which they were discharged and sieved with 0.63mm sieve size. The oversize materials were recycled until they all passed through the 0.63mm sieve. At this point, the samples prepared were worked upon: (a) 15 kg Itakpe iron ore pulverized to – 0.63 mm sieve size (b)15kg Agbaja iron ore pulverized to – 0.63mm sieve size.

Figure 3.: Shows the crushed Itakpe Iron ore prior to pulverization

Figure 4: Shows the crushed Agbaja Iron ore prior to pulverization

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1.5kg blended iron ores were weighed with Itakpe iron ore in the blend-1425g. (95%) and Agbaja iron ore in the blend-75g.(5%). The Salter Digital weighing balance with trademark – Mettler Pm 2000 was used to weigh the samples. The weighed samples were charged into a clean and moisturefree Erich 2287 Palletizing Disc Machine of 35cm diameter wide palletizing disc. 4% lime was added into the machine. The operational procedure of the machine was allowed to rotate 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 works gradually; while the charge was scrapped on a continuous basis to avoid sticking to the disc. As the experiments progress the pellets of varying diameters ranging from (15 mm balls – 320 pieces, 20mm balls-320 pieces, 25mm balls-320 pieces, 30 mm balls -320 pieces and 40mm-320 pieces) were formed. The 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 5: Shows the pulverized Itakpe iron ore

Figure 6: Shows the pulverized Agbaja Iron ore

Figure 7: Show the bentonite used as a binding agent of the ores

Figure 8: Shows some resultant pellets from Itakpe Iron ore

Figure 9: Shows some resultant pellets from Agbaja Iron ore

Figure 10: Shows how some resultant pellets for both Itakpe and Agbaja iron ores as been dried in the normal atmospheric which is known as green pellets

Drop Number Test of Pellets from Height of 60cm

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

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

The drop resistance tests of the pellets from 48cm, 60cm and 72cm height were performed. Eight (8) green pellets samples from each group of blends produced were selected randomly. Eight samples were dropped for the drop resistance tests as measured from heights of 48cm, 60cm and 72cm. Efforts were made to see that the number of drop resistance continued until the samples fell and fractured into pieces. The number of failures was observed until the samples were fractured into piece. 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 tests for the drop resistance results were taken. Average values of the drop resistance test of the samples reading gave the actual drop resistance tests of the pellets.

Green Compressive Strength Test

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

Dry Compressive Strength Tests

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 a muffle furnace to 600^oC. After which they were subjected to load tests by 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 recorded. The values of the best six (6) pellets samples were taken and recorded. The average values of the compressed sample reading gave the actual dry compressive strength test of the pellets. Same procedures were applied to the rest of the pellets.

Indurating Compressive Strength Tests

The Indurating Compressive Strength Tests experiments were performed. Eight (8) samples of pellets were randomly selected and subjected to heating processes. The experiments were 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 the tested pellets in this group were fired in a heating furnace to a temperature of 1200^oC for one hour, before the samples were subjected to load tests using the Testometric testing machine with model number: M500-25CT. The readings of the scattered load tests were observed as the samples were placed under the testing machine until fracture occurred. The obtained values were recorded and the average of the readings of the best six(6) samples values were taken as the actual indurating compressive strength tests of the pellets. The same experimental procedures were repeated to the rest of the blends.

Moisture Content of Pellet in Each Blend

Eight (8) pellets samples were randomly selected from a set of group of blended pellets produced. The sample were 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), Department of the Metallurgical and Materials Engineering, Faculty of Engineering, University of Nigeria, Nsukka.

The moisture content of the samples were determined. The samples serves as a representative of the pellets of blends taken. The samples placed in the crucible were weighed with the same weighing scale and the readings were carefully recorded. The crucible and pellets were then transferred into a heating oven with model DHG-9101. A Laboratory Dry Oven located at the Nigerian Liquefied Natural Gas (NLNG) in the Faculty of Engineering, |University of Nigeria, Nsukka. The pellets were heated to the temperature of 105^oC. These processes were allowed for two (2) hours, after which they were brought out and weighed. The samples were allowed to cool at the atmospheric. The samples were later returned into the heating oven and reheated for another one (1) hour. The samples were allowed to cool and they were reweighed; this process was done severally until other values obtained for the required readings.

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

Micro-Porosity of Pellet in Each Blend

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The Micro-Porosity of the pellets were performed, the weighed pellets were heated to 900^{o}C using the muffle furnace, with model number LABE 1210, Divine International, Delhi. The samples were taken out of the furnace, and were dropped into a beaker containing benzene solution. Immediately this was done, there was the release of bubbles from the pellets which indicate that empty spaces in the pellets were filled with benzene displacing the blow of air filled with benzene. The displacing of the blow of air within the pellets was caused by the firing of the pellets. The samples were allowed to remain in benzene solution until the bubbles stopped. The pellets were brought out of the benzene solution and weighed immediately. This process was then repeated for all other samples from other blends.

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

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

Tumbler Resistance Test

The tumbler resistance tests were performed. In this case 60 Pellets of 95% Itakpe Iron ore and 5% Agbaja iron ore blend were taken and weighed at 600gms. The samples were fired and dried at 150^{0}c slowly in a heating furnace for two (2) hours. 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 seven (7) minutes at a speed of 24rpm. 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)

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

Abrasion Index value

The abrasion tests were carried out. 60 pellets samples of 95% Itakpe iron ore and 5% Agbaja iron ore blend weighing 600gms. The pellets samples were fired and dried at 150^{0}c. The process was slowly done in a heating furnace for two (2) hours. The samples were 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 seven (7) minutes at a speed of 24rpm. 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 the abrasion index (i.e. - 0.5mm).

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

Mechanical Properties of Resultant Pellets of Itakpe and Agbaja Iron Ore Blends

The mechanical properties of the blended iron ore resultant pellets were determined. The aim is to use the produced resultant pellets as burden materials to produce liquid pig iron in the blast furnace and in the Direct Reduced Iron (DRI) processes. The mechanical properties determined 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); Abrasion Index value(AIV) and Micro Porosity(MP) which constituents the major criteria in the investigation of the samples selected as blends for this research work The details of the results are shown on figures 11 - 19

Drop Number

Figure 11 indicates the variation of drop number ranging from 100 per cent of Itakpe Iron ore with an interval variation of 10 per cent until it 100 per cent of Agbaja Iron ore was obtained. From the graph obtained shows

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that the highest value of the drop number point was achieved at exactly at 3.89 cm. The corresponding blend ratio was at 70/30 Itakpe/Agbaja.

Figure 11: variation of Drop Number with various blends of Itakpe and Agbaja Iron Ore Pellets

Drop Resistance

Figure 12 indicates the variation of Drop Resistance value ranging from 100 per cent of Itakpe iron ore with an interval variation of 10 per cent until it 100 per cent of Agbaja iron ore was obtained. From the graph obtained shows that the best values of the drop resistance point was achieved. The best drop resistance was attained at Itakpe/Agbaja blend ratio at 64/40 with a corresponding value of 4.78cm.

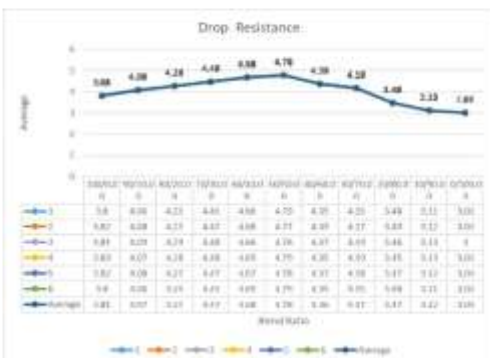

Figure 12 Variation of Drop Resistance with various blends of Itakpe andAgbaja Iron Ore Pellets

Green Compression

Figure 13 shows a variation of Green Compressive Strength with various blends of Itakpe / Agbaja Iron Ore Pellets. The best green compression strength tests values amongst the blend mixtures was achieved at 80/20 blend ratio of Itakpe/Agbaja with a corresponding value of 11.98N/P.

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Figure 13: Variation of Green Compressive Strength with various blends of Itakpe/Agbaja Iron Ore Pellets

Dry Compression

Figure 14 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 was achieved at 70/30 Itakpe/Agbaja blend ratio with green compressive strength of 34.7N/P.

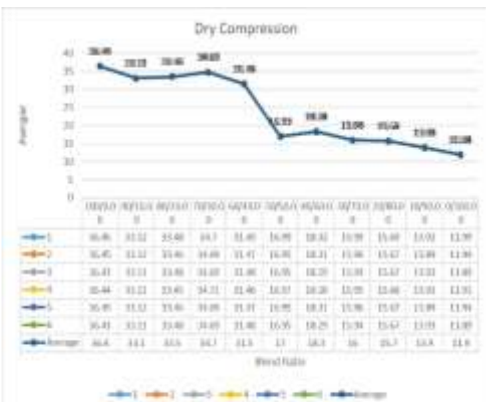

Figure 14: Variation of Dry Compressive Strength with Various blends of Itakpe/Agbaja Iron Ore Pellets

Indurating Compressive Strength Test @ 1200^{0}C (N/P)

Figure 15 shows a 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 was achieved at 70/30 Itakpe/Agbaja blend ratio with indurating compressive strength of 2592.40N/P.

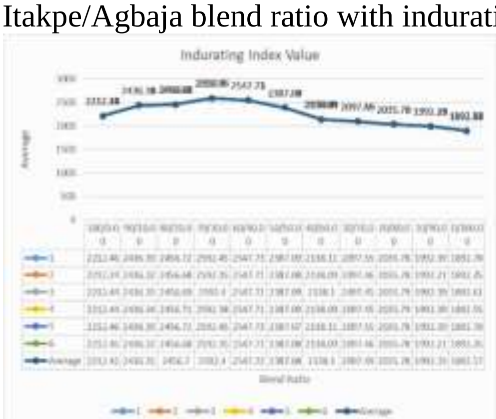

Figure 15: Variation of Indurating Compressive Strength with various blends of Itakpe/Agbaja Iron Ore Pellets

Moisture Content per Pellet (ml)

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Figure 16 shows the variation of moisture content with various blends of Itakpe/Agbaja iron ore pellets Itakpe/Agbaja blend ratios of 50/50 with moisture content value of 6.78ml.

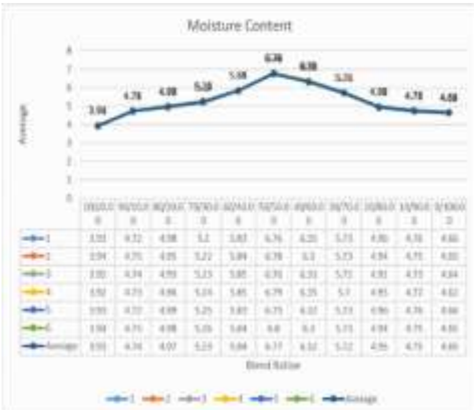

Figure 16: Variation of Moisture Content with Various blends of Itakpe/Agbaja Iron Ore Pellets

Tumbler Index Value Test (%)

Figure 17 shows a variation of the tumbler index with various blends of Itakpe/Agbaja iron ore pellets. Itakpe/Agbaja blend ratio of 60/40 has tumbler index value of 93.82% per cent

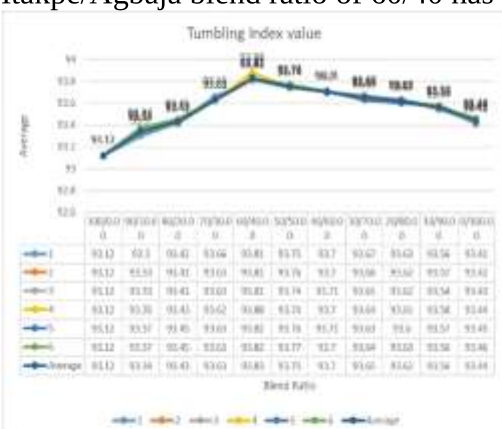

Figure 17: Variation of Tumbler Index with various blends of Itakpe/Agbaja Iron Ore Pellets

Abrasion Index Value (%)

Figure 18 show the variation of the abrasion index with various blends of Itakpe/Agbaja iron ore pellet. Itakpe/Agbaja blend ratio of 55/45 gave an abrasion index value of 5.14 per cent.

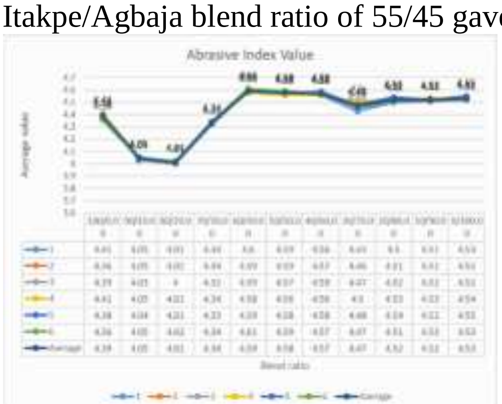

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Figure 18 Variation of Abrasion Index with various blends of Itakpe/Agbaja Iron Ore Pellet

Micro- Porosity of Pellet (%)

Figure 19 shows the best micro-porosity point achieved at Itakpe/Agbaja blend ratio of 10/90 with a value of 9.98%. According to this experiment, the velocity is always so high that even porosity variation between 9-30% hardly cause great differences and the major part of pellets qualities is within the upper limit of this range.

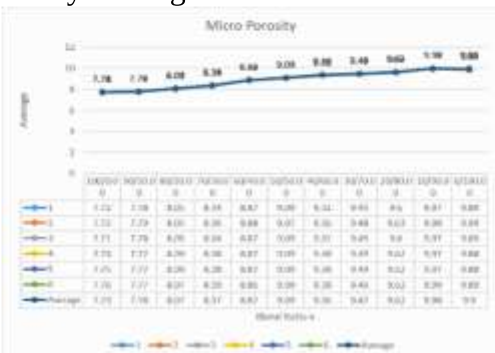

Figure 19: Variation of Micro-Porosity with various blends of Itakpe/Agbaja Iron ore Pellet

Findings and Contribution to Knowledge

The determination of the mechanical properties of the resultant pellets of the Itakpe and Agbaja iron ore blends were performed due to their importance in the production of pellets. The two ores are in some large quantity in Kogi State of Nigeria. The Itakpe iron ores are made up of highgrade ore, while the Agbaja iron ore consists of low grade. Following the principle of the production of materials burden in the Blast furnace and the Direct Reduced Iron it, therefore, became necessary to perform this research work on the possibility of blending the two ores together with a view to varying the blending ratio.

In this regards the research work was performed in order to expose all the relevant potentials attached to a blending of ores. From the research work, it was revealed that the resultant pellets satisfied all the standard parameters as regards the international and global practice. The resultant pellets will be able to meet the requirement for the operations of the furnaces at Ajaokuta and Aladja. From the research work performed on the determination of the mechanical properties of resultant pellets, it is important to state that the contributions to knowledge may be viewed in these ways:

(a) That the project was successfully completed and the data generated could be used as a data bank for those in this field of study.

(b) That the relevant data could assist the would-be researchers in process metallurgy. This research work has open a vista of the needed knowledge on the best methods and tools that could be used for the determination of mechanical properties of blend ores. This is with a view to blending the ores for the production of pellets that could be used as burden materials in the operation of the Blast furnace and the production of steel through the Direct Reduced Iron (DRI). **(c)** That the experimental techniques explored revealed that to the researcher some basic and important equipment and machines were used for the experimental processes. The mechanical properties were performed with a view to assisting the researchers and would researchers to understand the techniques and procedures to be used for the determination of the properties of the blended ores.

(d) The implications of these results are that the resultant pellets of the blends from Itakpe and Agbaja iron ore could be used as sources of materials for the production of wrought iron or pig iron at the Blast Furnace situated at the Ajaokuta Steel Company Limited, Ajaokuta in Kogi State. While that of the Direct Reduced Iron situated at the Delta Steel Company Limited, Aladja in Delta State.

Conclusions

The determination of the mechanical properties of the resultant pellets of Itakpe and Agbaja iron ore blends were intensively carried out. The studies carried out revealed the followings: **(a)** The mechanical properties determined showed that the sufficient mechanical strength of the resultant pellets was best achieved at 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 resultant pellets shows that there were presence of hygroscopic and hydrated water.

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