WASTE RESOURCE AGGLOMERATION MODULE (WRAM)

IRON ORE & CHROME WRAM ROX

Table of Contents

Introduction

The EESTech Waste Resource Agglomeration Module (WRAM) incorporates proprietary technologies entailing;

- the re-engineering of commercially available extrusion or pelletizing equipment, which are modified to accommodate unique process architecture.
- particle shaping and the chemical engineering of advanced binder formulations.

The proprietary process agglomerates waste materials sourced from course discard dumps and fines dams to produce a saleable product in the form of "WRAM ROX".

- A single line EESTech WRAM facility can agglomerate up to 250-tonnes per hour of wet or dry fines into highly compacted customized shapes and size as required for downstream furnacing.

- WRAM readily enables the blending of various minerals such as iron ore and coking coal to enhance smelting efficiencies through reduced energy consumption and increased production.

- The WRAM process permits the porosity of agglomerated WRAM ROX to be regulated to facilitate improved aeration and oxidisation efficiencies.

- The high pressure blending and particle shaping characteristics of the EESTech WRAM process allows for the potential bypassing of certain feedstock preparation processes such as sintering, providing opportunities to reduce finished product costs and energy consumption.

Regardless of the application, the high shear blending of EESTech's WRAM process produces a high quality product that is of consistent composition throughout with enhanced performance characteristics for downstream processing. WRAM ROX has been demonstrated to deliver a 30% reduction in downstream processing energy requirements and up to a 45% reduction in required carbon additives used by the furnace in the smelting process; equating to a substantial reduction in carbon emissions. Collectively delivering improved economic and environmental sustainability outcomes in waste material management.

EESTech "WRAM ROX" – Iron ore

The key highlights of the EESTech's iron ore agglomeration process includes;

- ✓ Capacity to agglomerate in excess of 250 tons per hour from a single process line.
- ✓ Cold curing at ambient temperature, negating the need for energy intensive thermal curing.
  - Advanced WRAM ROX formulations engineered to overcome the need to sinter to achieve necessary mechanical strength or required porosity.
- ✓ Engineered to achieve a crush load rating of up to 680kg per cm^2.
- ✓ Excellent green strength for efficient material handling and stock piling.
- ✓ Waterproof when cured.
- ✓ A porous formation at approximately 400°C to facilitate infusion of reduction gases.
- ✓ Produced in customised sizes and shapes.
- ✓ Reduces approximately 30% faster than lumpy iron ore.
- ✓ Remains stable in the smelting furnace and retains its form.
- ✓ Achieves Fe yields in excess of 62%.
- ✓ Reduces into good quality pig iron.
- ✓ An ideal additive to existing lumpy ore streams to increase porosity in the furnace charge.
- ✓ Delivers tangible financial benefits. .
- ✓ Mitigates the environmental impact of fine iron ore dust.
- ✓ Independently tested and validated by highly credentialed third parties.

EESTech "WRAM ROX" - Iron ore

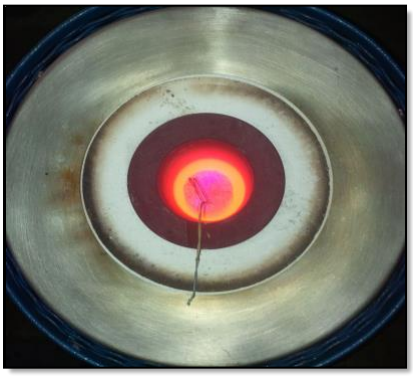
Laboratory Performance Testing

The breaking strength of WRAM ROX can be accurately varied from 10Kgs to over 600Kgs per cm^2, meeting the demands of bulk handling and multi stage transportation.

Destructive Index Testing

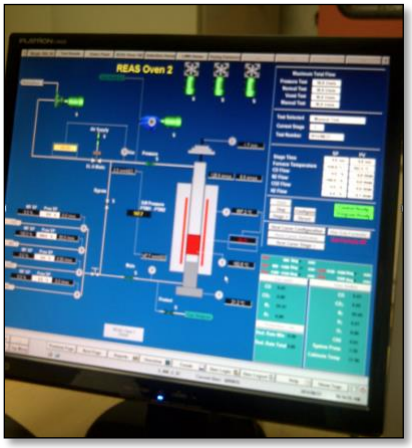
WRAM ROX is engineered to meet or exceed process specifications required for smelting with destructive index testing being one of the most challenging performance criteria.

WRAM ROX have been formulated and engineered to survive high thermal shock loads, including cold WRAM ROX being placed into pre-heated furnaces of over 750°C in order to test the performance as a feedstock in smelter conditions.



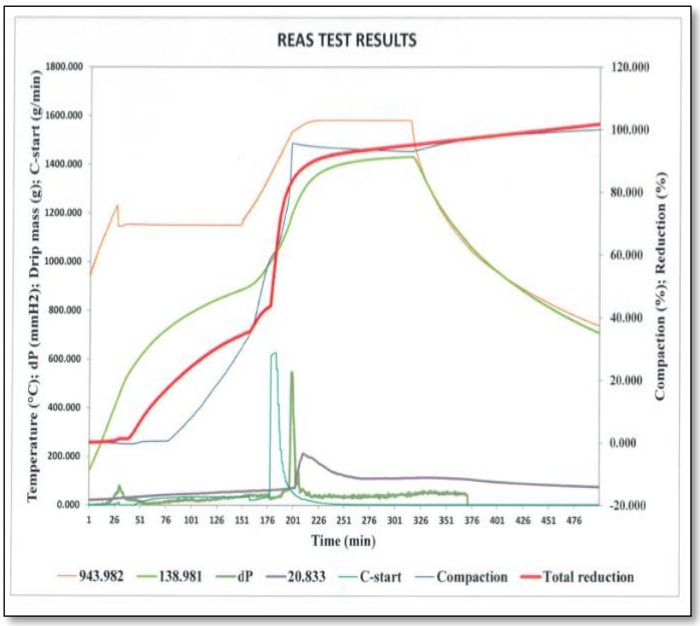
Chrome WRAM ROX being thermally shocked at 1000°C for 40 minutes in a test program, validating the structural integrity of WRAM ROX and proving their suitability for use as a smelter feedstock.

Iron ore WRAM ROX placed into test furnace pre-heated to 750^0_c for 30 minutes.

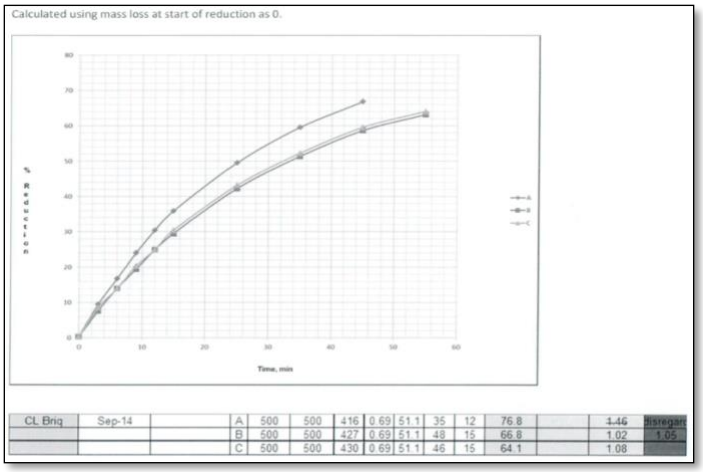


Simulated Smelting Tests

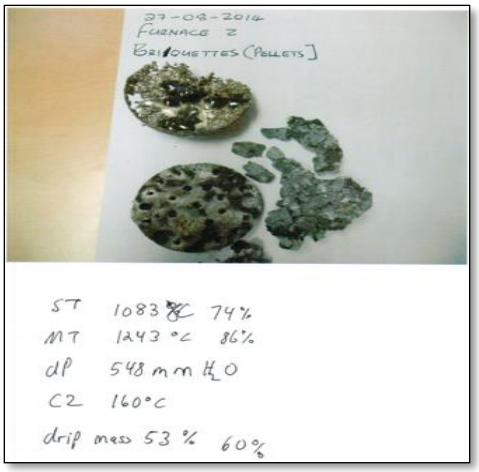
Reduction furnace designed to simulate the loading of a large-scale production furnace.



Red line indicates softening profile. WRAM ROX are ideal for providing porosity in the furnace charge for better reduction gas flow.



WRAM ROX reduces approximately 30% faster than lumpy iron ore, providing a significant savings in energy costs.



WRAM ROX achieved 98% Metallization in the simulated smelting furnace tests.

Commercial Production Furnace Basket Testing

Comprehensive production furnace "basket" tests were performed on EESTech's iron ore (hematite) WRAM ROX.

The objective of these tests was to determine the performance of the extruded WRAM ROX in a commercially operating reduction furnace and validate its suitability as a feedstock for smelting.

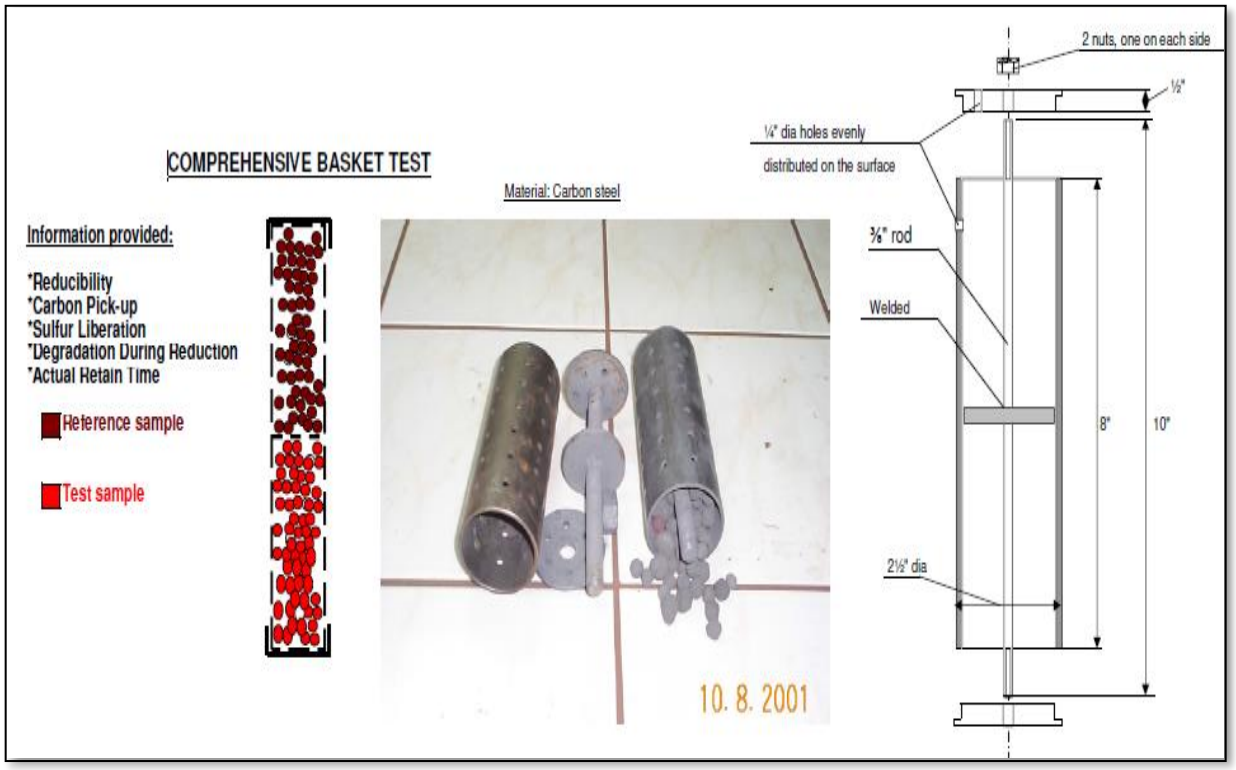
The two key performance criteria monitored were:

- The degree of splitting/breaking of WRAM ROX under reducing conditions in the furnace and the subsequent amount of fines generated.
- The percentage of metallisation of the WRAM ROX.

Methodology

The WRAM ROX samples were placed in a number of metal baskets, which permitted the through-flow of reducing (CO) gases.

Basket Test Apparatus



Preparation of test baskets prior to placement into furnace

Empty Test Basket

WRAM ROX Inside basket

Basket being placed in feed hopper

Basket in feed hopper

Test baskets containing WRAM ROX were placed into the feed hopper of the furnace every 30 minutes.
The retention time in the furnace varied between 18 and 23 hours.

Temperature profile inside the furnace

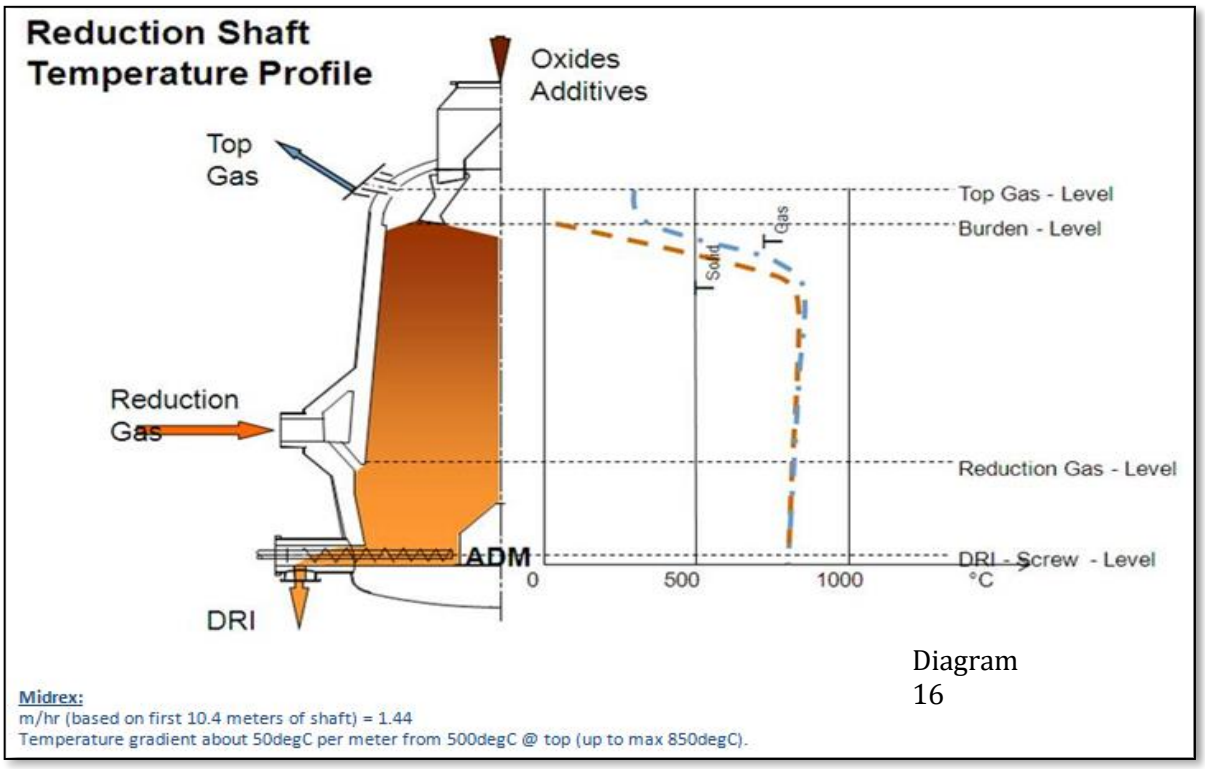


Diagram 16

The test baskets containing the WRAM ROX were introduced into the top of the furnace where the temperature was approximately 500 ˚C. The temperature increased to approximately 850 ˚C as the basket moved down the furnace shaft.

Test work results

The WRAM ROX exceeded test criteria. The integrity of WRAM ROX was maintained and no fines were produced.

Test Analysis

The sintered WRAM ROX were weighed and a sieve analysis was carried out to determine the amount and size fraction of fines produced. These weights were compared with the pre furnace weights to determine the percentage of mass loss that occurred in the furnace due to reduction of the ore.

The results of the WRAM ROX as compared to commercially available imported Brazilian sintered pellets that were used as a control.

WRAM ROX Test Analysis

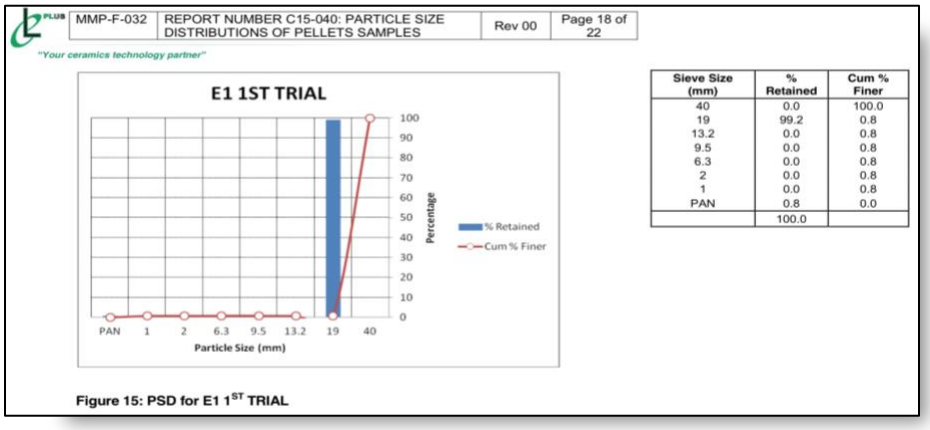
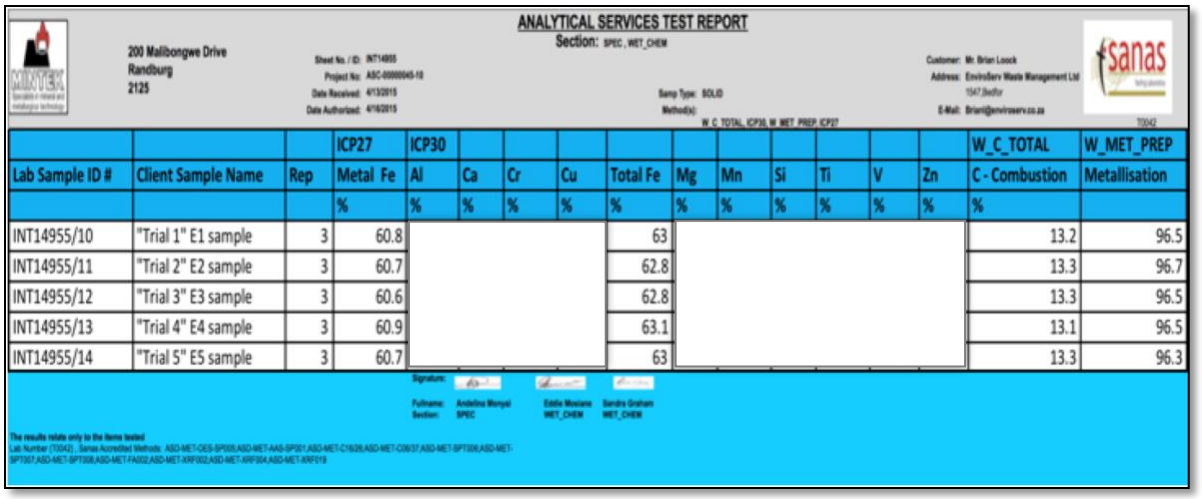


Figure 15: PSD for E1 1ST TRIAL

The WRAM ROX only produced a minimal 0.8% fines during the 18 to 23 hour reduction process in the furnace, concluding the reduction gases in the furnace will flow freely through the WRAM ROX charge and reduce the charge at an accelerated rate. The WRAM ROX blended with lumpy ore qualify as a suitable means of increasing the porosity of lumpy ore charges, increasing the rate of reduction and improving process efficiencies.

The WRAM ROX were also analysed for metallic Fe and total Fe in order to determine the percentage of metallisation. Test samples had a metallisation analysis of above 96%, this analysis illustrates the efficiency of WRAM ROX in a smelter and the energy savings that WRAM ROX can provide.


ANALYTICAL SERVICES TEST REPORT
Section: SPEC , WET_CHEM

200 Malibongwe Drive
Randburg
2125

Lab Sample ID #	Client Sample Name	Rep	ICP27 Metal Fe	ICP30 Al	Ca	Cr	Cu	Total Fe	Mg	Mn	Si	Ti	V	Zn	W_C_TOTAL C - Combustion	W_MET_PREP Metallisation
			%	%	%	%	%	%	%	%	%	%	%	%	%	
INT14955/10	"Trial 1" E1 sample	3	60.8					63							13.2	96.5
INT14955/11	"Trial 2" E2 sample	3	60.7					62.8							13.3	96.7
INT14955/12	"Trial 3" E3 sample	3	60.6					62.8							13.3	96.5
INT14955/13	"Trial 4" E4 sample	3	60.9					63.1							13.1	96.5
INT14955/14	"Trial 5" E5 sample	3	60.7					63							13.3	96.3

EESTech "WRAM ROX" - Conarc Dust

Conarc dust is generated during the smelting of lumpy ore, drawn from the smelter by the dust collection system. The conarc dust is then discharged from the cyclone and bag house filters for disposal.

Conarc dust has high iron content and can be readily agglomerated into WRAM ROX and recycled for smelting in the furnace. Agglomeration of conarc dust contributes to the reduction of environmental waste and the associated costs of waste management, whilst increasing operating efficiencies.

EESTech "WRAM ROX" – Chromite

Chromite fines are generated from the screening of lumpy chromite ore. The fines are milled and beneficiated into chromite concentrate. The concentrate is then pelletised as part of the preparation to the sintering process, where the chromite pellets take approximately 40 minutes to past through a furnace operating at a temperature of over 1,100^{o}C. The sintering of chromite ore pellets is a high energy cost process that is required prior to smelting.

EESTech's WRAM technology, which incorporates "cold cure" binder formulations, with a single WRAM process line producing up to 250tons of WRAM ROX per hour, without the requirement of thermal curing equipment or the energy costs of operating such equipment.

EESTech's Chromite WRAM ROX process also provides option for the addition of reduction and flux agents during palletisation, which can provide 30% efficiency improvement in downstream smelting. In effect this equates to a potential 30% savings in energy costs, which can be a significant market advantage.

EESTech "WRAM ROX" – Ferrochrome

Recovered ferrochrome fines from screening operations and chrome slag can be readily agglomerated into ferrochrome concentrated WRAM ROX. This product can be processed to meet the strictest destructive index standards, retains a very high crush resistant bond, is waterproof and can meet necessary export grade requirements. Ferrochrome WRAM ROX are suitable for downstream smelting and can be provisioned with reduction and fluxing agents infused into the processed product.

Designer WRAM ROX

Wram Rox can be custom made in almost any shape to meet client specifications or market requirements

EESTech "WRAM ROX" Summary

Comprehensive third party reviews, laboratory testing, product analysis and production furnace testing, have all been undertaken and have all validated the industry performance benchmarks being achieved by the EESTech WRAM ROX.

The WRAM process and WRAM ROX :

- ✓ exceeds the performance criteria required in all aspects of the smelting process.
- ✓ can be formulated to eliminate the need for sintering.
- ✓ porosity can be adjusted to improve smelting efficiencies
- ✓ reduction and flux modifiers can be readily blended
- ✓ achieve reduction efficiencies up to 30% faster than lumpy ore.
- ✓ achieve 96% metallisation
- ✓ can reduce the volume of carbon additives required for furnace smelting.
- ✓ can agglomerate saturated or dry, course discard, fines and conarc dust.
- ✓ can be produced as water resistant or water proof.
- ✓ single process line can deliver up to 250tph.
- ✓ cost effective deliverables.
- ✓ supports economic and environmental sustainability.

APPENDIX INDEPENDENT WRAM ROX TEST OBSERVATIONS

WRAM ROX Test Results

Introduction

WRAM ROX made from waste hematite fines were investigated as possible feedstock for iron making units in a blast furnace. The following tests were undertaken:

Reducibility Index (RI_{40})
Reduction Disintegration Index (RDI)
Decrepitation Index (DI)
Crushing Strength
REAS
Chemical Analysis.

Test Results

The test results are given in the table below:

Reducibility Index (RI_{40})	% / Min	1.1
Reduction Disintegration Index (RDI)		
$RDI_{+6.3}$	%	99.1
$RDI_{-3.15}$	%	0.9
Decrepitation Index (DI)		
$DI_{-6.3}$	%	0.2
Crushing Strength		
Specification	N	2000
Maximum	N	5852
Minimum	N	3886
Mean	N	4901
Median	N	4927
Range	N	1966
Standard Deviation	N	806
REAS		
Softening Temp	^oC	1082
Max Pressure Drop	mm	548
Melting Temp	^oC	1243
Relative Dripping Mass	%	53
Cohesive Zone	^oC	161

Observations

Reducibility Index (RI_{40})

The RI_{40} is a relative measure for evaluating the extent to and ease with which oxygen can be removed from iron ores, when reduced under conditions resembling those prevailing in the reduction zone of a blast furnace. Reducibility is import because it characterizes the extent to which a material is likely to be reduced in the lumpy zone of the BF (higher reduction is preferred). Tests are done in a reducing atmosphere of CO and N_2. The Reducibility Index is reported as the rate of reduction (%/Min) at 40% reduction of the ore. The RI_{40} value is used by European iron and steel makers. The reducibility rate of WRAM ROX is high at 1.1%/Min. This high reduction rate will increase the efficiency of the blast furnace.

Reduction Disintegration Index (RDI)

The reduction disintegration index of the WRAM ROX is found to be exceptionally good with little to no degradation during reduction.

Decrepitation Index (DI)

The thermal shock resistance (Decrepitation Index) of the WRAM ROX is excellent.

Crushing Strength

Crushing strength tests were conducted to determine the strength of WRAM ROX, and the compressive strength was evaluated by using the Instron compressive strength tester. Twenty (20) random WRAM ROX were tested and the results were recorded.

The average strength of the WRAM ROX was fare above the minimum strength of 2000N required for the blast furnace.

REAS

Softening Temperature (ST)

The material's softening temperature is the temperature, at which point the sample starts to yield and starts to soften, as a precursor to melting. The temperature where a pressure drop of 100mm H_2O is recorded is taken as the softening temperature.

The measured temperature was 1082 ^oC and is within the realm of acceptable regions for a hematite ore and should pose no adverse conditions in the blast furnace production.

Maximum Pressure Drop Over The Sample Bed (ΔP_{max})

The gas pressure drop over the bed increases as the sample softens. The temperature where the maximum pressure drop is recorded as well as the value of the pressure drop is used as indices.

The attained value of 548 mm is in the normal range.

Melting Temperature (MT)

The melting temperature is defined as the temperature where the pressure drop recovers to 100mm H_2O or lower, after dripping has occurred.

At 1243 ^oC this temperature is within acceptable limits.

Relative Dripping Mass

The relative dripping mass is a function of the total ass of the sample as is calculated after the test has been completed.

The recorded drip mass amounted to 53% and is acceptable for a pure ore in terms of reducibility.

Cohesive Zone

The cohesive is defined as the area between the melting and softening temperatures while the softening zone is defined as the area between the dripping and softening temperatures.

At 161 ^{o}C the WRAM ROX pellets should not lead to any adverse blast furnace conditions.

Chemical Analysis

The chemical Analysis showed that WRAM ROX would not have any undesired effects on the blast furnace or the quality of the iron being produced.

Conclusions

In summary, it can be concluded, that WRAM ROX have the necessary integrity to be used as feedstock for iron making units in blast furnaces. In fact, WRAM ROX will increase the efficiency of blast furnace operation and reduce energy demand.

WRAM ROX Case Study

An EESTech client in South Africa with significant volumes of iron ore fines engaged EEStech to engineer WRAM ROX that would not only offset the need to import iron ore pellets* from Brazil but endeavour to improve their iron ore smelting efficiencies through potential cost savings and or increased productivity.

* Brazilian pellets imported at a cost in excess of ZAR1,000 per ton (approximeately US$90 per ton) are utilised in the smelting process to accelerate reduction and maintain the flow of lumpy iron ore through the furnace.

Reductant (Carbon) Savings

The client currently utilises a 38.56% carbon to iron ore loading in their furnaces to achieve the desired metallization of the iron ore feedstock.

Through the introduction of EESTech formulated WRAM ROX incorporating the blended addition of only 8% carbon with local iron ore fines, a 96% metalization standard can be achieved. This represents a 75+% reduction in the amount carbon required to acheive metalization.

Cost saving analysis:

Substituting 223,000 tons per annum (tpa) of imported pellets with WRAM ROX containing an 8% carbon loading represents a carbon cost saving of approximately R81,777,600 per annum.

Calculations:

- 223, 000 t of imported pellets x 38.56% = 85, 988 tpa of carbon
- 223, 000 t of WRAM ROX x 8% = 17,840 tpa of carbon
- Carbon savings of: 68, 148 tpa x ZAR1, 200 per ton = ZAR81, 777,600

Electricity Savings

WRAM ROX were demonstrated to reduce 30% faster than lumpy ore translating to a 30% reduction in electricity consumption in the production of pig iron.

Calculations:

It was reported that approximately 1, 400 kWh was required to reduce 1 ton of lumpy ore into pig iron:

- 1, 400 kWh x ZAR0.39 per kWh = ZAR546 per ton of reduced pig iron.
- R546 per ton x 223, 000 tons of Brazilian pellets = R121, 758, 000.

WRAM ROX reducing 30% faster equates to a 30% reduction in electricity usage delivering an approximate saving of ZAR36, 527, 400 per year.

Increased Production

With WRAM ROX reducing 30% faster than lumpy ore, equates to a potential 30% increase in production , providing the client with a significant competitive edge.

Carbon Fines Removal

The client is further challenged with the task and cost of managing the removal of carbon fines generated by the handling of carbon-based products used in the steel making process. Classified as a waste product the carbon fines were shown to be readiliy agglomerated into WRAM ROX converting an environmental liability into a valued product.

Conarc Dust

Conarc dust disposal is an additional operational liability the client is challenged with. With Conarc dust high in iron content, it is able to be blended into WRAM ROX and recycled back to the furnace for conversion into pig iron.

Summary Outcome

EESTech's WRAM technology and WRAM ROX were able to deliver a significant range of tangible benefits through the reduction of environmental liabilities, improved production efficiencies and financial gain.