CHAPTER 5

5.1 DISCUSSION

5.2 SUMMARY

5.3 REFERENCES
5.1 DISCUSSION

The physical, chemical, mineralogical, thermal and thermo-mechanical properties of magnesia carbon bricks of four compositions "A", "B", "Am-B" and "A-Bm" made out of FM-A and FM-B are evaluated and attempt is made to correlate their properties.

5.1.1 Chemical Composition

In chemical composition, the loss on ignition at 1000°C for all four compositions is found to be similar as the quality and quantity of graphite, phenolic resin binder and Al-metal powder are same in all four compositions. The RC of the bricks is derived from the carbon content of graphite and phenolic resin binders added. From 10% graphite the residual carbon would be 9.7% and 0.8% from phenolic resin binders. The total RC is 10.5%(9.7%+0.8%). But the LOI values are lower than 10.5%. This is because during oxidation firing in LOI test, Al-metal powder gets oxidized to Al₂O₃ and increases the weight of the residue after LOI test. For achieving correct value of RC, Al₂O₃ correction factor has to be applied. After Al₂O₃ correction factor, the RC of all four compositions matches with the composition.

Each composition has 90% of fused magnesia and both FM-A and FM-B have identical MgO content. There is slight increase in SiO₂, Fe₂O₃ of the bricks in composition to the chemical composition.
of the parent magnesia. During oxidation of carbon in LOI test the 
carbon of graphite is oxidized and ash is left in the residue. The 
chemical composition of ash and oxidation of Al metal powder to 
Al₂O₃ causes increase in the Fe₂O₃, SiO₂ and Al₂O₃. The 
incorporation of SiO₂ from ash of graphite also alters the CaO:SiO₂ 
ratio than the chemical composition of fused magnesia used.

5.1.2 Properties after drying at 180°c
The physical properties after drying at 180°c such as AP, BD, CCS 
MOR and MOE are identical. This is because FM-A and FM-B have 
similar grain bulk density. The granulometric compositions are 
identical. The size of graphite and the quantity of resin binder are 
same. Bricks were manufactured under identical conditions such as 
mixing and pressing. Therefore the physical properties at ambient 
temperature are identical.

5.1.3 Properties after coking at 1000°c
The properties after coking at 1000°c such as AP, BD, CCS, MOR 
and MOE are identical but different from the physical properties after 
drying at 180°c. During coking of bricks at 1000°c the volatile matter 
of resin escapes out leaving behind some open space i.e., pores 
inside the bricks. The resin polymer produces carbonaceous bond.
Some of the Al-metal powder is converted to Al₄C₃. Because of this reason bricks after coking have higher coked porosity and lower bulk density than bricks dried at 180°C. The CCS, MOR and MOE are also lower than bricks dried at 180°C. The expansion observed in PLC is due to the formation of Al₄C₃ and MgO.Al₂O₃ spinel during coking. The PLC values of all four brick compositions are same as all four brick compositions have same quantity of Al metal powder and graphite. The expansion of magnesia component at 1000°C is negligible because there is no liquidus phase formation at this temperature and hence PLC is due to formation of Al₄C₃ and MgO.Al₂O₃ spinel.

5.1.4 Properties after coking at 1400°C

The properties of the bricks of four compositions after coking at 1400°C are not identical as observed in case of bricks after drying at 180°C and after coking at 1000°C.

Brick B has the lowest AP i.e, 9.5%. Brick A has the highest AP i.e., 11.6%. AP of bricks Am-B and A-Bm is in between brick A and B and the values are 10.5% and 10.2% respectively (Table 16). Lowest porosity of brick B is due to the higher shrinkage behavior of FM-B which constitutes the complete magnesia component than that of FM-A which constitute complete magnesia component of brick A.
Both brick Am-B and A-Bm have 50% magnesia aggregate of FM-A and FM-B. Therefore their AP figures are in between brick A and brick B.

The shrinkage behaviour of fused magnesia as discussed above is quite evident from the PLC values at 1400°C fired in reducing atmosphere. Brick B has the lowest PLC value and brick A has the highest value. PLC values of Am-B and A-Bm are in between brick A and brick B (Table 16). All the four bricks have same amount of graphite and Al-metal powder. The expansion due to the formation of $\text{Al}_4\text{C}_3$ and $\text{MgO}\cdot\text{Al}_2\text{O}_3$ will be same for all four bricks, and the difference in expansion property is due to the shrinkage property of fused magnesia used.

The MOR indicates the bonding strength of the bricks, which is controlled by the sintering property of brick. The MOR at ambient temperature after coking at 1400°C is the highest for brick B and the lowest for brick A. Brick Am-B and brick A-Bm have the values in between brick A and brick B (Table 16). The MOR of brick A-Bm is slightly higher than brick Am-B though both the compositions have 50% each of FM-A and FM-B in their magnesia component. The brick A-Bm has FM-B in the matrix in finer fraction whereas in brick Am-B FM-A is present in matrix in finer fraction. In the study of the sintering behaviour of FM-A & FM-B, it was observed that finer
fraction of FM-B has higher degree of sintering than FM-A. The reason of high degree of sintering of FM-B has been discussed in Chapter 3.6. Page 80.

The MOR, MOE and CCS signify the bonding characteristics of the bricks, which are controlled by the sintering properties of brick. All these three properties show the same trend.

5.1.5 Thermal and Thermo-Mechanical Properties

5.1.5.1 Thermal Shock Resistance

Thermal Shock resistance of four magnesia carbon bricks are evaluated and represented in the form of index (Table 16). Lower index indicates higher thermal shock resistance (Fig:15). Kenji Ichikawa et.al (38) have reported that the increase of graphite content in magnesia carbon bricks reduces the number of cracks and increase of Al-metal powder increases the number of cracks. In the present study four magnesia carbon bricks have the same amount of graphite and same amount of Al-metal powder. Therefore the difference in thermal shock resistance is due to the different application method of magnesia component. The thermal shock index of brick A is taken as 100.

Thermal shock index of Brick A is the lowest and that of brick B is the highest. Thermal shock index of Brick Am-B and A-Bm are in
between brick A and brick B. Takahiro Azuma et. al. (121) studied the thermal characteristics of magnesia carbon bricks. According to the study, the ratio of high-temperature strength and sonic elastic modulus has been correlated between crystallite size and grain boundary thickness. Fused magnesia having average crystal size of 600 & 400μm and lesser grain boundary thickness had large S/E (S= high temperature strength and E= Sonic Elasticity modulus) values and high thermal shock resistance. It is important to have a good balance between MgO crystal size and grain boundary bonding for improved thermal shock resistance. FM-A used in brick A has larger periclase crystal size than FM-B used in brick B. Brick Am-B and brick A-Bm have 50% each of FM-A and FM-B in their magnesia component. Therefore their thermal shock resistance is in between brick A and brick B. However, in brick Am-B the matrix part is of FM-A therefore the thermal shock resistance is slightly higher than Brick A-Bm.

The fracture energy of the brick i.e., MOR:MOE ratio after coking at 1400°C are in correlation to their thermal shock resistance. Higher the MOR:MOE ratio indicates higher fracture energy and consequently higher thermal shock resistance.
**5.1.5.2 Oxidation Resistance**

The oxidation resistance at 1400°C in normal furnace atmosphere is measured in terms of the oxidation depth (Fig:16). The oxidation mostly is due to the following reason:

\[
C + O_2 \rightarrow CO_2 (\text{gas})
\]

All the four compositions have the same amount of graphite and Al-metal powder as antioxidant. The difference in depth of oxidation observed is in accordance with the coked porosity of the bricks after coking at 1400°C. Brick B having the lowest coked porosity allows less infiltration of air resulting less oxidation depth. Brick A has the highest coked porosity, which allows more infiltration of air resulting more oxidation depth. Oxidation depth of brick Am-B and brick A-Bm are in between brick A and brick B (Table 16). Oxidation depth of brick A-Bm is slightly less than Am-B because of FM-B in matrix of A-Bm helps more sintering.

**5.1.5.3 Hot Modulus of Rupture**

The hot strength of bricks are measured by their hot modulus of rupture property at 1400°C. The Hot modulus of rupture is controlled by the formation of \(Al_4C_3\) and \(MgO\cdotAl_2O_3\). The hot modulus of rupture...
of brick A and brick B are 83Kg/cm² and 77Kg/cm². The hot modulus of rupture value of brick B is lower than that of brick A (Table 16).

All four compositions have the same amount of graphite and aluminium metal powder. Therefore the contribution by the formation of Al₄C₃ and MgO.Al₂O₃ for hot modulus of rupture will be the same for all four compositions. The lower hot modulus of rupture of brick B is due to the low melting silicate phases of FM-B used in magnesia component of brick B. The hot modulus of rupture of brick A is higher than brick B inspite of brick A has lower sintering property than brick B. This is because in brick A FM-A is used as magnesia component. FM-A has large periclase crystal and direct bonding between periclase to periclase. The silicate phases of FM-A have higher melting temperature than FM-B. Brick Am-B and brick A-Bm have higher hot modulus of rupture value than brick A and brick B. The higher value for brick Am-B and brick A-Bm is due to better sintering property of FM-B which constitutes 50% of the magnesia component of brick Am-B and A-Bm. Brick Am-B has higher hot strength than brick A-Bm because the matrix part of brick Am-B constitutes of FM-A.

5.1.5.4 Slag Corrosion and Erosion Resistance

After rotary drum slag corrosion and erosion test the erosion depth is measured and recorded. From erosion depth, wear index is
calculated. The wear index of brick A is taken as 100. Brick having lower wear index indicates higher corrosion and erosion resistance. Brick B has wear index of 116. Brick Am-B and A-Bm have wear index in between Brick A and brick B (Table 16). The wear index of brick Am-B is 78 and that of A-Bm is 88 (Fig 17).

Among all four brick compositions, brick B has the lowest coked porosity at 1400°C. Also oxidation resistance at 1400°C is the lowest. But its hot modulus of rupture at 1400°C is the lowest. The wear index is also highest. Brick B has 100% FM-B in its magnesia component. The corrosion resistance of FM-B is lower than FM-A as discussed in chapter no 3.6. FM-B has low periclase crystal size and more grain boundary. Periclase crystal disintegrates to smaller sizes by reaction with slag (Fig 23A, 23B). This phenomenon weakens the bond of Brick B and consequently high erosion of the brick.

Brick A has better corrosion resistance property than brick B inspite of brick A having higher coked porosity than brick B at 1400°C. Brick A has 100% FM-A in its magnesia component. As discussed earlier FM-A has higher periclase crystal size than FM-B which is the prime reason of brick A having higher corrosion resistance and lower wear index in comparison to brick B (Table 16).

Brick Am-B & A-Bm have lower wear index than Brick A and Brick B (Table 16). Amongst Am-B and A-Bm, brick Am-B has lower
wear index than brick A-Bm. The presence of 50% FM-B increases the sintering property and lowering the coked porosity in comparison to brick A. The lower coked porosity minimizes the depth of penetration of slag and causes less erosion. In the corrosion test, normally matrix of the bricks gets attacked first and subsequently the grains of the brick. As brick Am-B has FM-A in matrix part the attack is less consequently less erosion in comparison to the brick A-Bm where FM-B is in matrix. FM-A has high corrosion resistance than FM-B.

5.1.5.5 Microstructure after corrosion with slag

The microscopic examination of all four brick samples is carried out in reflected light under optical microscope on polished section prepared from the brick-slag interface upto cold end. The observations are as follows:

The penetration of slag and reaction zone of brick A, B, Am-B and A-Bm are found to be 2.28mm, 1.90mm, 1.02mm and 1.43mm respectively.

In brick A only FM-A has been used. FM-A has higher corrosion resistance than FM-B (ref Chapter no 3.6, Page 81) but brick A containing only FM-A shows higher wear index. From
microscopic studies it is found that the slag and metal penetrates more deeply into the brick as brick A has high coked AP. The reaction of periclase with slag and disintegration to minute particles is comparatively lower than brick B. The mechanism of erosion of brick A is due to loosening of the bond and consequently higher abrasion loss by metal (Fig 22A).

Brick B shows the highest wear index even though it has the lowest coked porosity. FM-B shows poor corrosion resistance to slag as discussed in Chapter 3.6. Microscopic studies of brick B after slag corrosion test also shows the similar phenomenon (Fig 23 A & B). Brick slag interface and slag penetrated zone shows higher degree of disintegration of periclase crystals than brick A. The depth of slag penetration in brick B is less than brick A. It may be due to the fact that the reaction of slag on brick interface is faster consequently erosion is rapid which exposes new brick surface. The higher degree of disintegration of periclase crystals is due to the effect that periclase crystals are enveloped by low melting silicates like CMS, C₃MS₂ having melting temperature less than the test temperature of slag corrosion test. This leads to loosening of the silicate phases and makes easier for slag invasion.

In brick Am-B and A-Bm the wear index is lower than brick A and brick B. In both composition 50% of FM-A and FM-B has been
used. Because of the high sintering property of FM-B, both compositions have lower coked porosity than brick A. Therefore penetration of slag is lower. Brick Am-B shows lower wear index than A-Bm. This is because of the fact that Am-B has FM-A in the matrix. From microscopic studies it is observed in Am-B (Fig 24 A & C) that slag penetrates to pores of the matrix but its reaction with periclase is comparatively lower than brick A-Bm (Fig 25 A & C). Normally, after erosion of the matrix the grains are attacked by slag. In brick Am-B FM-A being present in matrix shields the magnesia grain from the attack of slag. This phenomenon results high corrosion resistance of brick Am-B.
5.2 SUMMARY

Two types of natural Fused magnesia of Chinese Origin termed as FM-A and FM-B were taken for study. Their chemical, physical, thermo-mechanical and mineralogical properties were evaluated. From the evaluation of the results it was observed that:

- The MgO content of both fused magnesia is same but the CaO:SiO$_2$ ratio is 4.37:1 for FM-A and 1:1 for FM-B. The Al$_2$O$_3$+Fe$_2$O$_3$ content of FM-A is lower than FM-B.

- Grain bulk density is similar for both the fused magnesia.

- Periclase crystal size of both the fused magnesia is different. Average periclase crystal size of FM-A is 421$\mu$m and that of FM-B is 250$\mu$m.

- The mineralogical observations showed that silicate phases are more in boundary in case of FM-B than in FM-A. Silicate in FM-A is C$_2$S and C$_3$S and that of FM-B is C$_3$MS$_2$ and CMS.

- FM-B has higher degree of sintering property than FM-A at 1600$^\circ$C. The higher shrinkage of FM-B is due to higher degree of liquid phase at 1600$^\circ$C, which is due to the presence of low temperature melting silicate phases and higher Al$_2$O$_3$+Fe$_2$O$_3$ content. It is confirmed from the fact that FM-B has higher compressional creep value at 1600$^\circ$C than FM-A.

- In the slag corrosion test it was found that FM-A shows higher corrosion resistance to synthetic ladle furnace slag than FM-B. The mechanism of corrosion is penetration of slag into the grain.
boundary and disintegration of periclase crystals to minute crystals sizes. This phenomenon is more in FM-B than in FM-A.

Four compositions of Magnesia Carbon bricks with 10% graphite content were made from these two fused magnesia FM-A & FM-B. In all four compositions, quantity and quality of graphite, Al-metal powder, phenolic liquid resin, phenolic powder resin and hexamine are kept same. Only the distribution of FM-A and FM-B in different sizes is changed.

The four formulations are named as "A", "B", "A-Bm" and "Am-B".

- In the formulation “A”, only fused magnesia FM-A is used in all three fractions.
- In formulation “B” only fused magnesia FM-B is used in all three fractions.
- In formulation “A-Bm”, FM-A is used in coarse and middle fraction along with FM-B in coarse, middle and fines fraction. The composition is termed as A-Bm because FM-B is used in fine fraction which constitutes the matrix of the bricks.
- In formulation “Am-B”, FM-A is used in coarse, middle and fine fraction along with FM-B in coarse and middle fraction. The composition is termed as Am-B because FM-A is used in fine fraction, which constitutes the matrix of the bricks.

Composition A-Bm and Am-B have FM-A and FM-B in 1:1 ratio but their fine fraction is different. Magnesia carbon bricks of all four
formulations are made under identical manufacturing conditions such as:

- Granulometric composition
- Mixing sequence
- Pressing techniques
- Drying schedule

Magnesia carbon bricks were evaluated for chemical, physical, thermal, thermo-mechanical & mineralogical properties. The observations are as below:

**Chemical Composition:**

- LOI and RC values are similar for all four formulations.
- MgO of all four formulations are identical because the fused magnesia FM-A and FM-B used have identical MgO content.
- The ash of graphite has contributed for slight increase in SiO₂ and Fe₂O₃ of the compositions.
- Increase in Al₂O₃ is due to oxidation of Al-metal powder added in the formulations.

**Properties after drying at 180°C**

The physical properties after drying at 180°C such as AP, BD, CCS, MOR and MOE are identical (Fig 26,27,28,29,30 and Table 17). This is because FM-A and FM-B have similar grain bulk density. The granulometric compositions are identical. The size of graphite and the quantity of resin binder are same. Bricks were manufactured...
under identical conditions such as mixing and pressing. Therefore the physical properties at ambient temperature are identical.

**Properties after Coking at 1000°c**

The properties after coking at 1000°c such as AP, BD, CCS, MOR and MOE are identical but different than the physical properties after drying at 180°c(Fig 26,27,28,29,30 and Table 17) During coking of bricks at 1000°c the volatile matter of resin escapes out leaving behind some open space i.e., pores inside the bricks. The resin polymer produces carbonaceous bond. Some of the Al-metal powder is converted to $\text{Al}_4\text{C}_3$. Because of this reason bricks after coking have higher coked porosity and lower bulk density than bricks dried at 180°c. The CCS, MOR and MOE are also lower than bricks dried at 180°c. The expansion observed in PLC is due to the formation of $\text{Al}_4\text{C}_3$ and $\text{MgO.A}_2\text{O}_3$ during coking(Fig 31 and Table 17). The PLC values of all four brick compositions are same as all four brick compositions have same quantity of Al-metal powder and graphite. The expansion of magnesia component at 1000°c is negligible because there is no liquidus phase formation at this temperature and hence PLC is due to formation of $\text{Al}_4\text{C}_3$ and $\text{MgO.A}_2\text{O}_3$.

**Properties after coking at 1400°c**

The trend of AP, CCS, MOR, MOE and PLC is as follows :

**AP:**

\[ B > A > B_m > A_m > B > A \]
The variation in AP is due to the higher shrinkage behaviour of FM-B than that of FM-A (Fig 26 and Table 17).

**CCS (Fig 28 and Table 17)**
\[ A > A_m-B > A-B_m > B. \]

**MOR (Fig 29 and Table 17)**
\[ A > A_m-B > A-B_m > B. \]

**MOE (Fig 30 and Table 17)**
\[ A > A_m-B > A-B_m > B. \]

The MOR, MOE and CCS at ambient temperature after coking at 1400°C depends upon the sintering property. Sintering property of FM-A is higher than FM-A and this controls the MOR values.

**PLC (Fig 31 and Table 17)**
\[ B > A-B_m > A_m-B > A. \]

PLC values at 1400°C fired in reducing atmosphere is due to the formation of \( \text{Al}_4\text{C}_3 \) and \( \text{MgO}\cdot\text{Al}_2\text{O}_3 \), which will be same for all four bricks, but the difference is due to the shrinkage property of magnesia used.

**Thermal Shock Index**

The trend of thermal spalling index is as follows:
\[ A > A_m-B > A-B_m > B. \]

The difference in thermal spalling resistance is due to the different application method of magnesia component. The fracture energy of the brick i.e., MOR:MOE ratio after coking at 1400°C are in correlation to their thermal shock resistance (Table 17).
**Oxidation Resistance**

The trend of oxidation resistance is as follows (Table 17):

B > A-Bm > Am-B > A.

The difference in depth of oxidation observed is in accordance with the coked porosity of the bricks after coking at 1400°C. Also better the sintering property less will be the depth of oxidation.

**Hot Modulus of Rupture**

The trend of Hot modulus of rupture is as follows (Table 17):

B > A > A-Bm > Am-B

The Hot modulus of rupture is controlled by the formation of Al₄C₃ and MgO·Al₂O₃ during firing under reducing condition, presence of silicate phases and sintering property.

**Corrosion by Slag**

The trend of corrosion (in mm) is as follows (Table 17):

Am-B > A-Bm > A > B.

Corrosion by slag is influenced by periclase crystal size, sintering property of the matrix and presence of silicate phases. Larger the periclase crystal size and also better sintering of the matrix resulted in less erosion. Presence of low melting silicate phases causes higher erosion. This is confirmed by microscopic study.

Correlation of the chemical, physical, thermal and thermo-mechanical properties of the four formulations A, B, Am-B and A-Bm reveals that formulation Am-B has superior properties in corrosion, oxidation, thermal spalling and hot strength.
Magnesia carbon bricks are used for the lining of high temperature steel manufacturing furnaces such as Electric Arc furnace (EAF), L D converter and secondary refining ladles. For achieving higher campaign life in the aforesaid furnaces magnesia carbon bricks to be used should have balanced chemical, thermal, thermo-mechanical and corrosion resistance properties. From the present research work it is found by using only one fused magnesia in magnesia carbon bricks balanced chemical, thermal, thermo-mechanical properties are not achievable. The combination of two high grade fused magnesia having more than 97% (MgO) and their selection is very important. Out of the two fused magnesia, one should have large periclase crystal size and CaO:SiO₂ ratio more than 3:1 and another type should have small periclase crystal size and CaO:SiO₂ ratio 1:1. The former contributes to improve the corrosion resistance and the later improves the sintering property. The technique of blending also plays an important role to achieve the balanced properties. The best formulation is to use the fused magnesia having large periclase crystal size and CaO:SiO₂ ratio more than 3:1 in the matrix and the coarse and middle fraction to be the mixture of both the type of fused magnesia.

The present research work will be a tool to refractory industries to design magnesia carbon brick for balancing their thermal, chemical, physical, mineralogical and corrosion resistance properties.
Fig 26: Trend of Average AP of Magnesia Carbon bricks at three different test temperatures

<table>
<thead>
<tr>
<th>Temperature</th>
<th>A</th>
<th>B</th>
<th>Am-B</th>
<th>A-Bm</th>
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<tr>
<td>180°C</td>
<td>3.2</td>
<td>3.3</td>
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<tr>
<td>Coking 1000°C</td>
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<td>8.7</td>
<td>8.6</td>
<td>8.5</td>
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<tr>
<td>Coking 1400°C</td>
<td>11.6</td>
<td>9.5</td>
<td>10.5</td>
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Fig 27: Trend of Average BD of Magnesia Carbon bricks at three different test temperatures

<table>
<thead>
<tr>
<th>Temperature</th>
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Fig. 28: Trend of Average CCS of Magnesia Carbon bricks at three different test temperatures

Fig. 29: Trend of Average MOR of Magnesia Carbon bricks at three different test temperatures
Fig 30: Trend of Average MOE of Magnesia Carbon bricks at three different test temperatures

<table>
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<tr>
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<th>A</th>
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<th>Am-B</th>
<th>A-Bm</th>
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<tr>
<td>Coking 1400°C</td>
<td>38.0</td>
<td>58.0</td>
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Fig 31: Trend of Average PLC of Magnesia Carbon bricks at two different test temperatures

<table>
<thead>
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<td>Coking 1400°C</td>
<td>0.84</td>
<td>0.60</td>
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Table 17: Properties of Four compositions : Individual data and Average Figures

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<tr>
<th>Composition No</th>
<th>A</th>
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<th>Am-B</th>
<th>A-Bm</th>
<th>A-Bm</th>
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<td><strong>Chemical Composition (weight%)</strong></td>
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<td>LOI</td>
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<td>8.92</td>
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<td>CaO</td>
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<td>0.60</td>
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<td>3.96</td>
<td>3.82</td>
<td>3.96</td>
<td></td>
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<tr>
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<td>0.61</td>
<td>0.50</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>CaO:SiO₂</td>
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<td>2.80</td>
<td>1.62</td>
<td>1.74</td>
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<tr>
<td><strong>Properties after drying at 180°C</strong></td>
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</tr>
<tr>
<td>AP(%)</td>
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<tr>
<td>BD(gm/cc)</td>
<td>3.02</td>
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<tr>
<td>CCS(Kg/cm²)</td>
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</tr>
<tr>
<td>MOR(Kg/cm²)</td>
<td>205</td>
<td>190</td>
<td>157</td>
<td>198</td>
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<tr>
<td>MOE(Gpa)</td>
<td>68.6</td>
<td>68.2</td>
<td>57.1</td>
<td>66.4</td>
<td>67.6</td>
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<tr>
<td><strong>Properties after Coking at 1000°C</strong></td>
<td></td>
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</tr>
<tr>
<td>RC(%)</td>
<td>10.5</td>
<td>10.5</td>
<td>10.6</td>
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<tr>
<td>AP(%)</td>
<td>8.5</td>
<td>8.1</td>
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<tr>
<td>BD(gm/cc)</td>
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<td>CCS(Kg/cm²)</td>
<td>260</td>
<td>268</td>
<td>255</td>
<td>264</td>
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<tr>
<td>MOR(Kg/cm²)</td>
<td>101</td>
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<td>MOE(Gpa)</td>
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<td>34.2</td>
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<tr>
<td>PLC(%) (+)</td>
<td>0.43</td>
<td>0.42</td>
<td>0.41</td>
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<tr>
<td><strong>Properties after Coking at 1400°C</strong></td>
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<tr>
<td>AP(%)</td>
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<td>261</td>
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<td>MOR(Kg/cm²)</td>
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<tr>
<td>PLC(%) (+)</td>
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<td><strong>Thermal &amp; Thermo-mechanical Properties</strong></td>
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<td>Oxidation(mm)</td>
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<td>13.6</td>
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<td>13.8</td>
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<tr>
<td>Oxidation at 1400°C</td>
<td>13.7</td>
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<td>13.6</td>
<td>13.9</td>
<td>13.8</td>
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<td>HMOR(Kg/cm³),at 1400°C</td>
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<td>Slag Erosion (mm)</td>
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<td>Wear Index</td>
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<td>88</td>
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