HOT ABRASION RESISTANCE OF SOME LOW CEMENT CASTABLES

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HOT ABRASION TESTS- CONTENTS

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BACKGROUND AND STANDARDS

ABRASION

- Particles moving with high velocity.
- Charge of material or scrap falling against the refractory and damages lining.
- Blast furnace, cement preheaters and cooling zone, incinerators, boilers, rotary kilns , lime kilns, and aluminium furnaces.

ABRASION TESTING

- Cold abrasion is the guideline in the design (ASTM C704 or ISO16282-2007).
- Correlations established with CMOR,CCS,MOE, and AP.
- Changes in the surface nature during use.
- Effect of temperature and other thermo-mechanical-chemical interactions.

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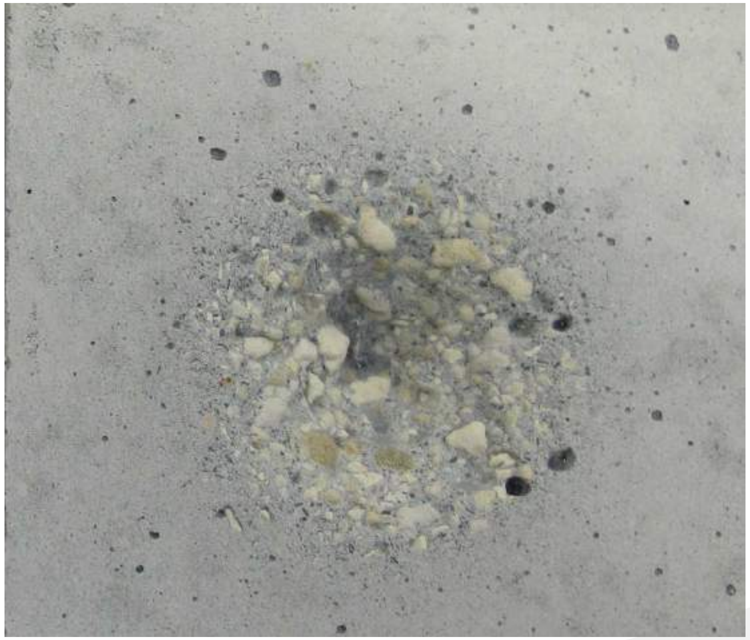
HOT ABRASION TESTING

- Reports avaialable since 1930s.
- Continuous improvement in designing abrasion testing apparatus for high temperature measurements ongoing.
- The recent designs of apparatus for testing abrasion resistance of refractories consider the effects of all the variables in the design and abrasive media (SiC, Alumina type).
- Especially, the design of high temperature abrasion testing apparatus imposes serious concerns in design to maintain homogeneity of temperature and pressure during high temperature testing .



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HOT AND COLD ABRASION TESTING

This test method measures the volume of abraded material from a flat surface by blasting.

Pressure of 0.45MPa - 1000 grams of 36 grit SiC, at right angle to the surface- 900 Sec

The pre-fired samples were tested both at room temperature and at high temperatures (up to 1350°C) .

Abraded volume = [(W1-W2)/ D], cc

ISO 16349:2015 – FIRST EDITION
Refractory materials -- Determination of abrasion resistance at elevated temperature

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HOT ABRASION MEASUREMENTS – SiC CONTAINING MATERIALS WITH AND WITHOUT ANTIOXIDANTS

SiC containing castables.

- Al_2O_3-SiO_2-SiC castable finds widespread use in various applications such as cement pre-heaters, incinerators etc.
- Addition of SiC improves the resistance against chemical corrosion, abrasion? and thermal shock in applications.
- A major problem often faced is oxidation of SiC at higher addition level, when the temperature is above 900°C (even at low temperature + moisture) . The application temperature of alumino-silicate castables containing various amounts of SiC can go up to 1300°C and this affect the performance of castables due to oxidation.

- SiC + 2O2 $\longrightarrow$ SiO2 + CO2
- SiC+ 3/2O2 $\longrightarrow$ SiO2 + CO
- SiC+ O2 $\longrightarrow$ SiO2 + C

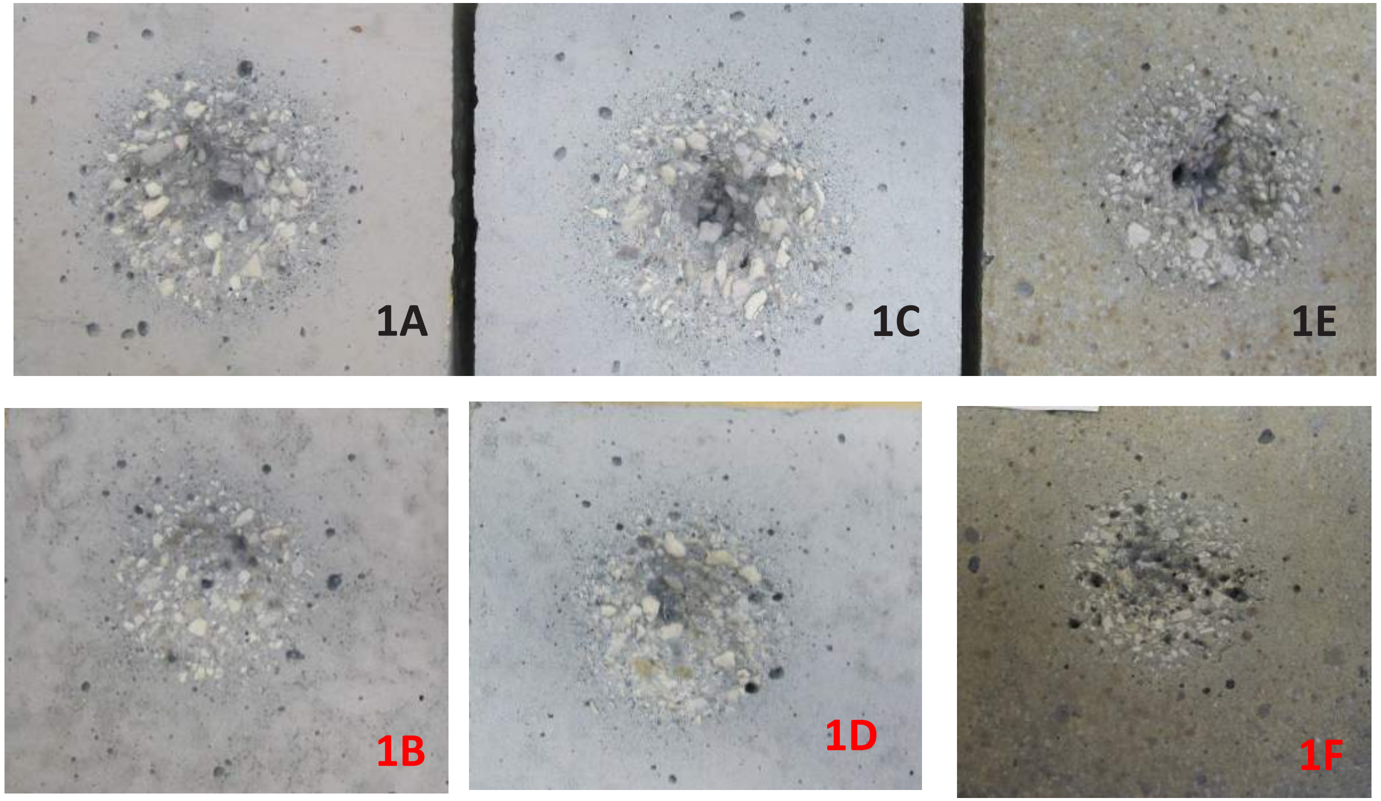
- To overcome the oxidation problem, antioxidants are often used and thus retain the properties of castables. This study explores the effect of an antioxidant, B_4C, on the cold and hot abrasion of a 30% SiC containing castables up to 1300°C. It has been noticed that B_4C addition protected SiC and drastically reduced the abrasion loss at high temperatures

Pre-firing temperature, °C	Testing temperature, °C	No B_4C	2.0% B_4C
800	RT	1A	2G
800	800	1B	2H
1100	RT	1C	2I
1100	1100	1D	2J
1300	RT	1E	2K
1300	1300	1F	2L

DETAILS OF LC CASTABLE

Chemistry , %	Samples
Al_2O_3	30
SiO_2	35
CaO	2.5
SiC	30
B_4C	0 and 2.0
H_2O	7.5

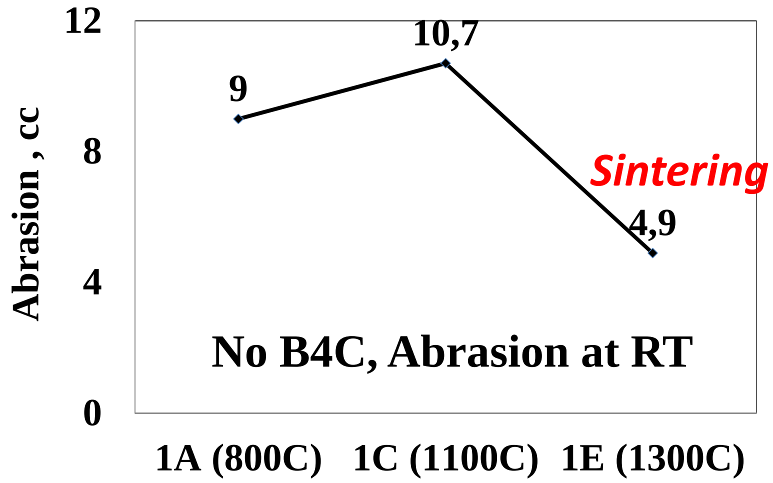
NO B4C

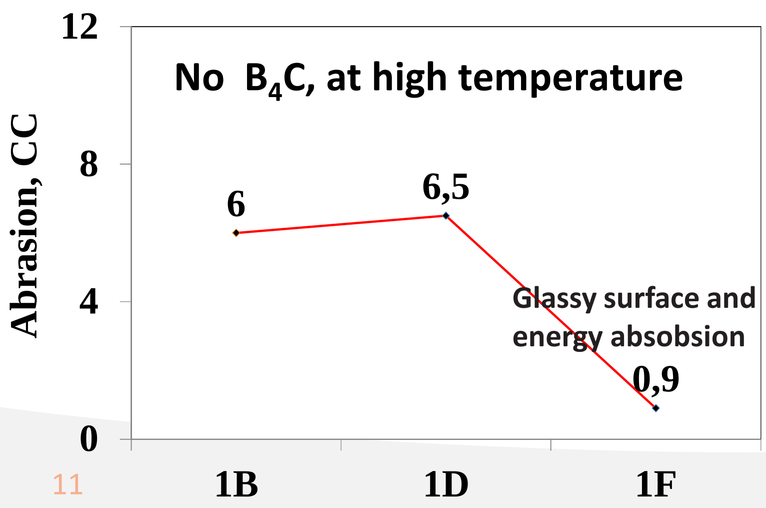


Pre-firing temp, °C	Testing temp, °C	No B_4C
800	RT	1A
800	800	1B
1100	RT	1C
1100	1100	1D
1300	RT	1E
1300	1300	1F

- CONICAL
- MATRIX REMOVAL
- TRANSITION TO UNIFORM ABRASION

NO B4C





Pre-firing temperature, °C	Testing temperature, °C	Samples Name Without B_4C
800	RT	1A
800	800	1B
1100	RT	1C
1100	1100	1D
1300	RT	1E
1300	1300	1F

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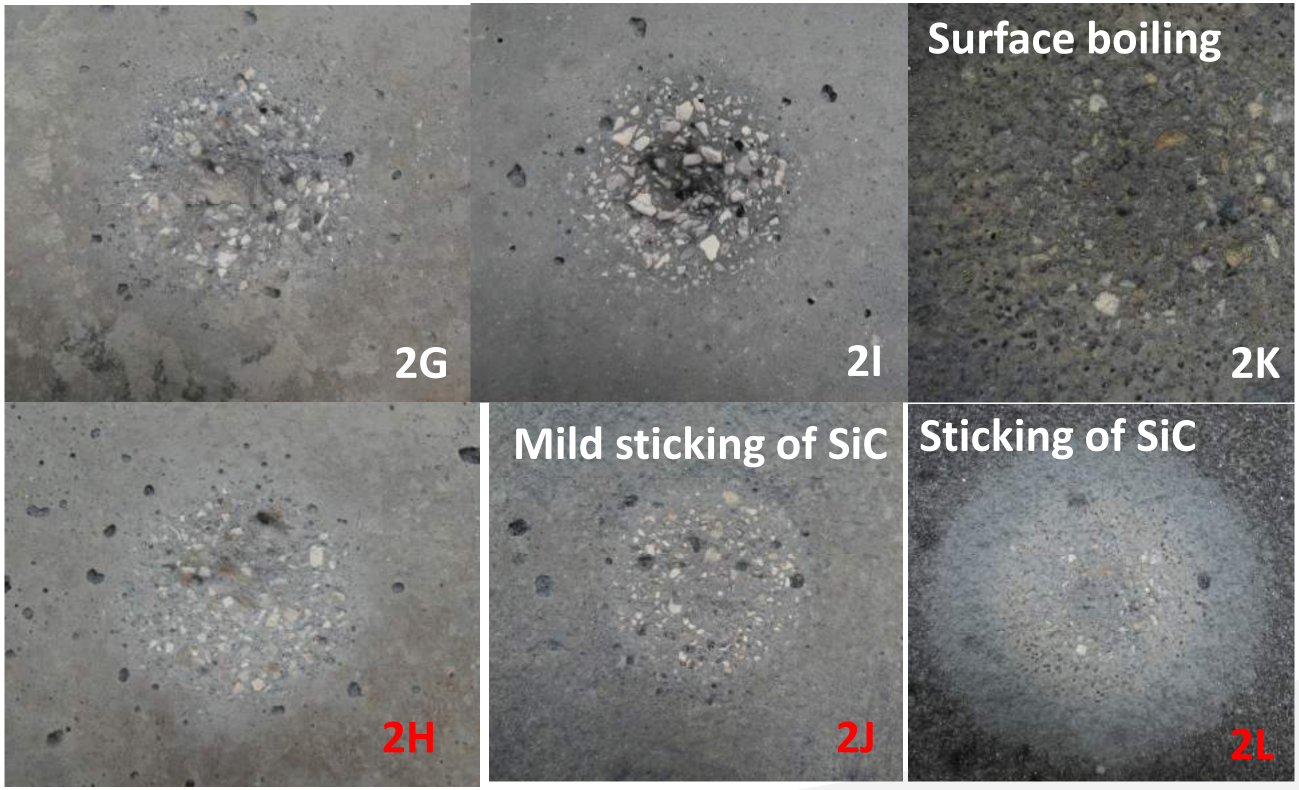
B4C

Pre-firing temperature, °C	Testing temperature, °C	2.0% B_4C
800	RT	2G
800	800	2H
1100	RT	2I
1100	1100	2J
1300	RT	2K
1300	1300	2L



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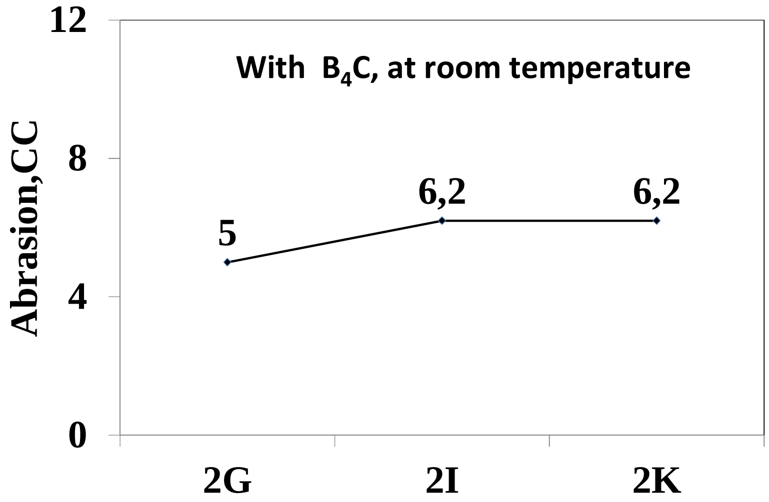

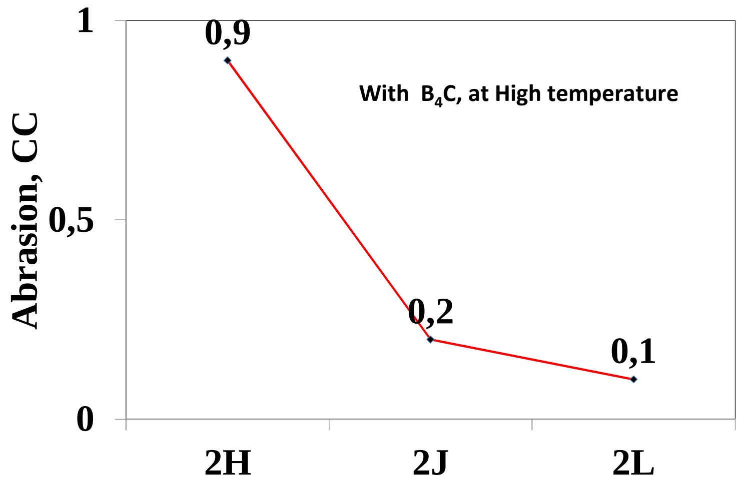

Pre-firing temperature, °C	Testing temperature, °C	2.0% B_4C
800	RT	2G
800	800	2H
1100	RT	2I
1100	1100	2J
1300	RT	2K
1300	1300	2L

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CONCLUSIONS

The high temperature testing of an alumino-silicate castable containing 30% SiC, with and without addition of an antioxidant B_4C has resulted in different abrasion patterns and varying volume losses. Addition of B_4C has protected SiC from oxidation.

The abrasion pattern is resembling conical in almost in all cases and circular for samples with 2% B_4C, pre-fired and tested at 1100 and 1300ºC respectively.

The B_4C addition has drastically reduced the abrasion of samples at high temperatures (even near to zero) due to the formation of glassy phase on the surface.

Effects of grain size distribution and temperature on abrasion resistance

CASTABLES

Ingredients, %	LCC1	LCC2	LCC3
60% alumina aggregate Calcined alumina, Fume silica, Calcium aluminate cement additives	Various		
Max grain size, mm	10	5	3
Casting Water, %	5.5	5.5	5.5
Bulk Density, g/cc			
After 110°C	2,58	2,56	2,57
After 815°C	2,51	2,52	2,51
After 1100°C	2,52	2,51	2,51

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HIGH TEMPERATURE ABRASION MEASUREMENTS

Pre-firing temperature, °C	Testing temperature, °C
815	RT
815	815
1100	RT
1100	1100

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ABRASION MEASUREMENTS

RT Measurements

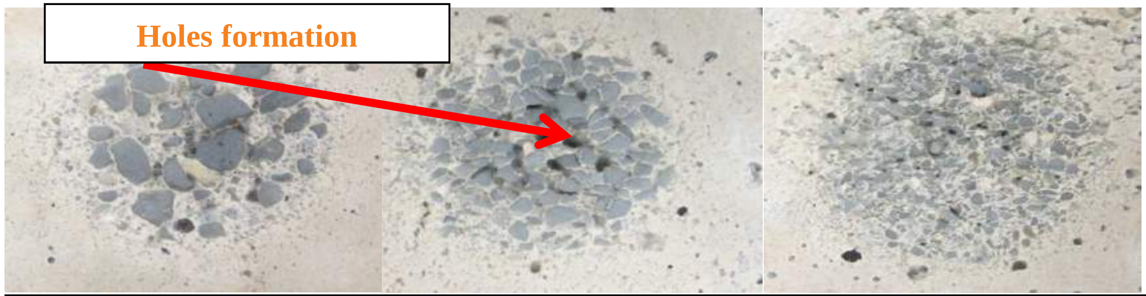
LCC1	LCC 2	LCC 3

Fired at 815°C and tested at RT

Matrix removal is the primary abrasion mode and the coarse grains are less abraded. Also, the abrasion tends to be conical pattern. This is the case in all 3 LCCs with various grain sizes distribution. The loss incurred is though removals of surrounding matrix followed by dislodging coarse grains.

ABRASION MEASUREMENTS

RT Measurements



LCC1	LCC 2	LCC 3

Fired at 1100°C and tested at RT

The samples fired at 1100°C have shown the formation of holes which is the result of grain pull out through the abrading mechanism.

The reason for this trend is the weakness of matrix compared to grains at room temperature.

HIGH TEMPERATURE ABRASION MEASUREMENTS

LCC1	LCC 2	LCC 3

Pre-fired and tested at 815°

- **Less conical pattern with uniform abrasion of both fine matrix and coarse grains.**
- **Attributed to the changes in elastic properties a as well as the thermal expansion characteristics making matrix stronger against abrasion.**

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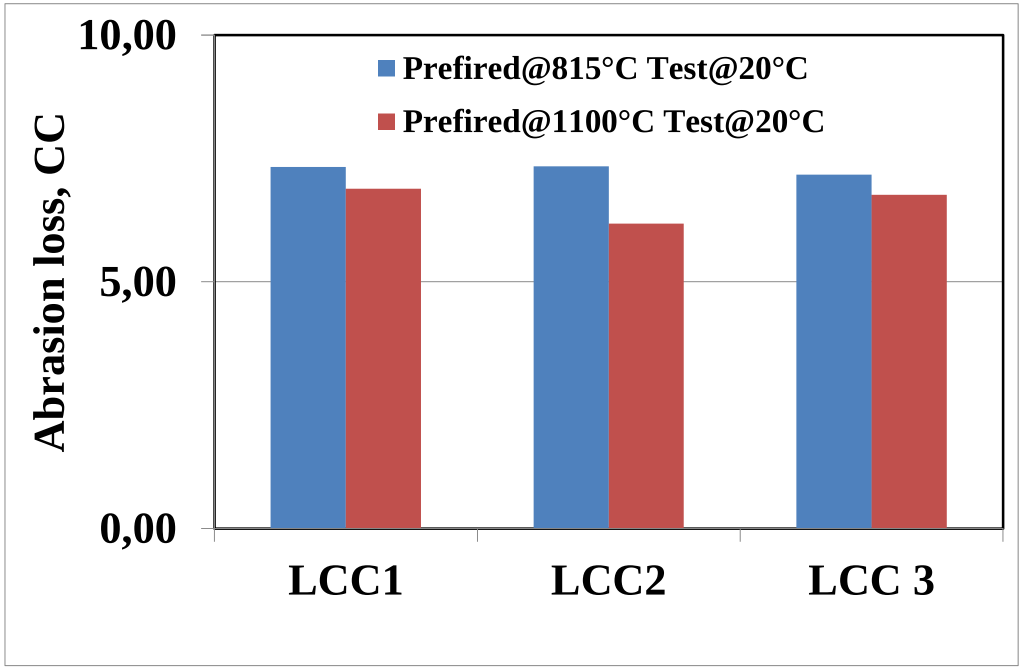
ABRASION MEASUREMENTS- PREFIRED AT HT AND TESTED AT RT



Abrasion loss at room temperature is at same level for all castables irrespective of changing grain size distribution.

Minor improvement of abrasion resistance for the samples tested at 1100°C. This is the result of mild sintering happening at that temperature.

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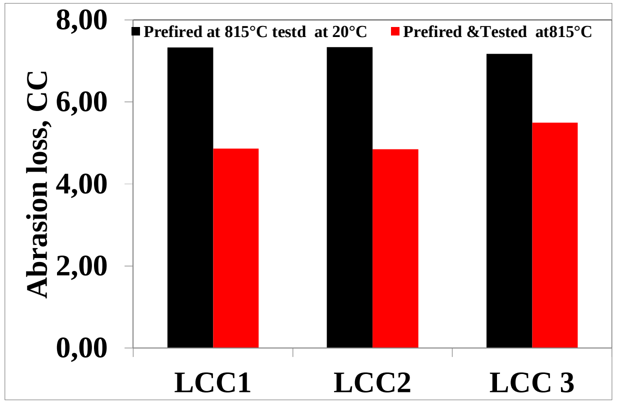
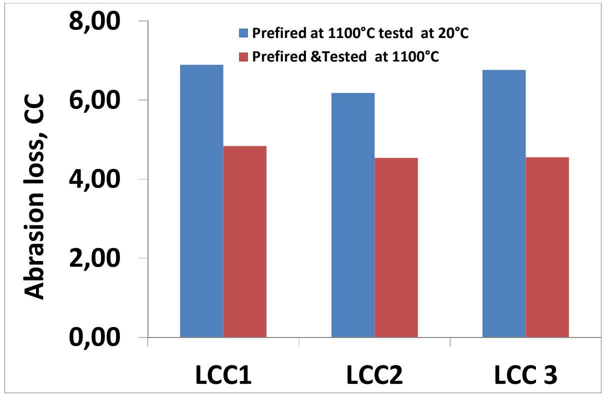
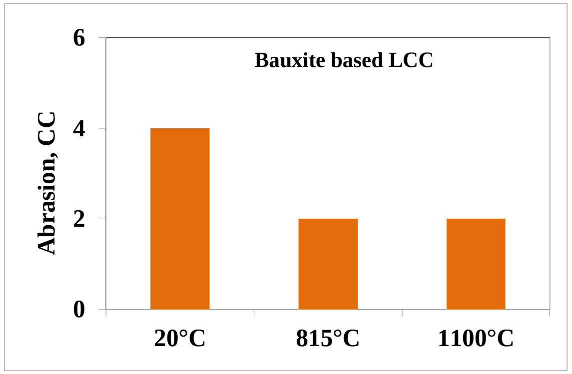
HIGH TEMPERATURE ABRASION MEASUREMENTS

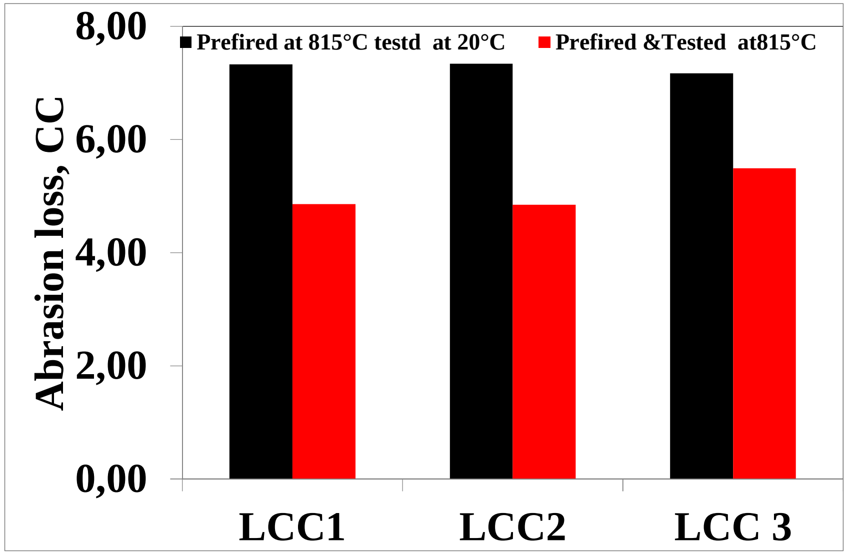




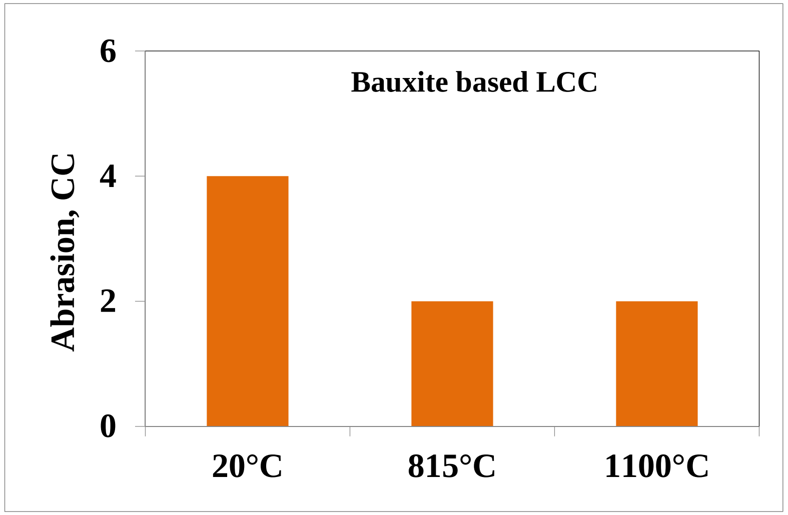


- **Abrasion resistance at high temperatures- 30% less loss at both testing temperatures**
- **No significance difference in abrasion loss between testing temperatures or change of granulometry.**
- **Change in elastic properties is the key- especially for the castables below the temperature of liquid formation (>1200°C).**

60% Alumina castables



Bauxite based LCC



Materials Selection Process

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CONCLUSIONS

- Change of granulometry doesn't affect the abrasion loss significantly both at high and RT measurements.
- Increasing testing temperature has resulted in 30% reduction in abrasion loss with the current testing method for the chosen castable.
- Thermo-physical changes in castables plays a vital role in abrasion mechanism.