INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

PRODUCTION OF LIGHTWEIGHT REFRACTORY INSULATION PANELS ON THE BASIS OF PERLITE

A.S.Mohajer[1], S.Ghanbarnezhad[1,2,*], L.Sharifi[1], S.H.Mirhosseini[1],Y.M.Irvani[1]
[1] Academic Center for Education, Culture and Research, Yazd Branch, Iran
[2] Department of Material Science Engineering, Science and Research branch Islamic Azad University, Tehran, Iran
*Correspondence Author: s.ghanbarnezhad@yahoo.com

Keywords: Insulation refractory, Perlite, Lightweight, Sintering, Mullite**.**

Abstract
For saving energy in industrial furnaces, various forms of insulation are used such as bricks, blocks, castable and fibers. Lightweight refractory insulation panels on the basis of Perlite (~30 wt.%) with chemical bonding (H_3PO_4) were successfully prepared by Extruding technique after sintering at 900-1100 °C. Properties such as density, sintering shrinkage percent, permanent linear change (PLC) and cold crushing strength are measured. The particle morphology was directly imaged by using scanning electron microscopy (SEM) and mineral phases present in the samples were determined at room temperature by using X-Ray diffraction patterns. According to results, samples with 30 wt.% Perlite with Phosphate bond in the range of 950-1000 °C to have the desired properties such as strength~ 30-35 Kgf/cm^2, density~ 0.42-0.45 g/cm^3 and application temperature at ~ 1100 °C.

Introduction
At a global level, environmental pollution from brick-making operations contributes to the phenomena of global warming and climate change. Also, extreme weather may cause degradation of the brick surface due to frost damage [1-3]. Global warming and environmental pollution is now a global concern. Cellular light weight technology blocks can be used as an alternative to the red bricks, to reduce environmental pollution and global warming [1]. These are high porosity refractories with low thermal conductivity used in order to reduce the rate of heat flow (heat losses) and thus to maximize heat conservation within the furnace. These have lower densities. The three basic types of insulating materials for industrial use are: a) thin (less than 20 micrometers), low-density fibers made from organic or inorganic materials; b) cellular material in closed or open cell form made of organic or inorganic material; and c) flaked or granular inorganic materials bonded in the desired form. In most cases, glass (silica), mineral wool, high alumina, mullite, or zirconia are the base materials and can be used to temperatures as high as 1400 °C.

This class of materials has a lower density and offers higher thermal resistance compared to firebricks. In all cases, thermal conductivity of the insulation increases significantly as temperature increases [4-6].

High-temperature processes require a considerable amount of energy. Often the energy consumption for high-temperature processes is used only partially for the actual technical process and 30 to 40% energy escapes through the walls into the atmosphere. To optimize the energy use and to prevent its escape into the ambience, special materials called insulating refractories are necessary [5,7]. The function of insulating refractory is to reduce the rate of heat flow (heat loss) through the walls of furnaces. Insulation is effected by providing a layer of material having low heat conductivity, which means heat does not readily pass through them [8]. The desirable feature of insulating bricks is the low thermal conductivity, which usually results from a high degree of porosity. Structure of air insulating material consists of minute pores filled with air which have in them very low thermal conductivity. The air spaces inside the brick prevent the heat from being conducted but the solid particles of which the brick is made conduct the heat. So in order to have

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

required insulation property in a brick a balance has to be struck between the proportion of its solid particles and air spaces. The thermal conductivity is lower if the volume of air space is larger.
Importantly, the thermal conductivity of a brick does not so much depend on the size of pores as on the uniformity of size and even distribution of these pores. Hence, uniformly small sized pores distributed evenly in the whole body of the insulating brick are preferred [5, 9-10].
The high porosity of the brick is created during manufacturing by adding a fine organic material to the mix, such as sawdust. During firing, the organic addition burns out, creating internal pores. Other ways to accomplish high porosity involves: a) by using materials which expand and open up on heating; b) by using volatile compounds like naphthalene; c) by using aluminum (Al) powder in combination with NaOH bloating); d) by using substances which by themselves have open texture e.g. insulating brick grog, vermiculite, ex-foliated mica, raw diatomite etc; e) by using foaming agents to slip; f) by aeration etc. Because of their high porosity, insulating bricks inherently have lower thermal conductivity and lower heat capacity than other refractory materials. Insulating materials can be classified with respect to application temperature: a) Heat resistant insulating materials for application temperatures up to 900 °C: calcium silicate materials; products from siliceous earth, perlite or vermiculite; silica based micro porous heat insulators; alumino-silicate fibers; b) Refractory insulating materials for application temperatures up to 1200 °C: lightweight chamotte and kaolin bricks; lightweight castables; mixed fibers and aluminum oxide fibers; c) High refractory insulating materials for application temperatures up to 1500 °C: lightweight mullite and alumina bricks; lightweight hollow sphere corundum castables and bricks; special high refractory fibers; d) Ultra-high refractory insulating materials for application temperatures up to 1700 °C: zirconia lightweight bricks and fibers; non-oxide compounds; several other types of insulating refractories include castables, granular insulation, and ceramic fiber insulation, which is light weight [5, 11-12].
Extremely lightweight materials have a porosity of 75 to 85% and ultra-lightweight, high-temperature insulating materials have a total porosity greater than 85%. These are widely used in the crowns of glass furnaces and tunnel kilns. They can also be used as linings of furnaces where abrasion and wear by aggressive slag and molten metal are NOT a concern. a) Decreased heat losses through the furnace lining and less heat loss to the refractory leads to savings in fuel cost; b) The insulating effect causes a more rapid heat-up of the lining and lowers heat capacity of the insulating refractory; c) Thinner furnace wall construction to obtain a desired thermal profile; d) Less furnace mass due to the lower mass of the insulating refractory [5, 8-14].
So, the aim of this work is the production of the lightweight refractory insulation panels on the basis of perlite with chemical bonding (H_3PO_4) by Extruding technique.

Materials & methods

The starting materials were Perlite (~10-30 wt.%) and Balclay (70-90 wt.%) which in Table.1 and Table.2, are shown the chemical and experimental compositions of raw materials. These compositions were mixed in a laboratory blender for 15 min with water for increasing the strength used H_3PO_4 (~3-7 wt.%) as a binder. After forming and drying at 110 °C, sintering was done in different temperatures in the range of 900 °C-1100 °C for 3 hours in the maximum sintering temperature which in Fig. 1, shows the preparation route of lightweight refractory insulation panels by Extruding technique.

 ISSN: 2349- 5197

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

Table.1, the chemical compositions of raw materials

Oxide Raw Material (%)	**MgO**	**CaO**	**Al_2O_3**	**Fe_2O_3**	**SiO_2**	**TiO_2**	**K_2O**	**Na_2O**
Balclay	97.20	1.20	31.80	1.50	60.70	1.70	2.50	0.60
Perlite	0.70	1.30	11.90	4.80	70.60	0.00	3.90	2.60

Table.1, Experimental compositions

Samples Raw Material (%)	**P10**	**P20**	**P30**
Balclay	90	80	70
Perlite	10	20	30

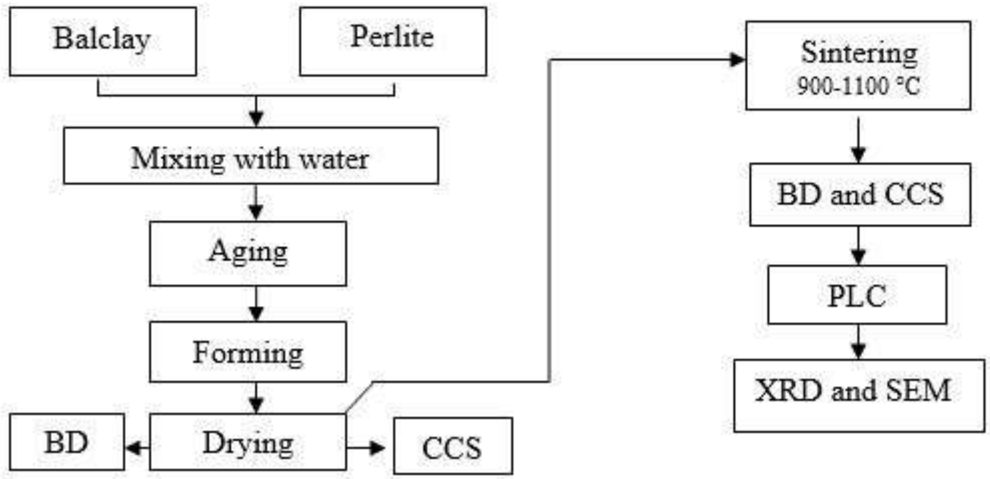


Fig. 1, preparation route of lightweight refractory

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

Results & discussion

Cold crushing strength study

Although, in refractory systems with ceramic (chemical) bonding strength strongly depends on the types of acting forces or stresses and the presence of imperfections. Ceramic-based materials, relatively brittle under tensile and bending stresses [15]. As shown in Fig. 2, the C.C.S diagram changing, it is observed by increasing temperatures the amount of strength increased. The sample P30 has not higher strength at 1100 °C when compared with the samples P10 and P20 that's whyfor insulation, porosity is required. According to Fig.3, equilibrium diagram on a ternary system of SiO_2-Al_2O_3-K_2O, the compounds located within the area of primary Mullitewhich involves the last phases such as Mullite, Quartz or Tridymite and Feldspar ($6SiO_2.Al_2O_3.K_2O$). According to Fig. 4, equilibrium diagrams on a ternary system of a) SiO_2-Al_2O_3-MgO, all of the samples compounds located within the area of Quartz or Cristobalite, Mullite and Cordierite, b) SiO_2-Al_2O_3-FeO(Fe_2O_3)and c) SiO_2-Al_2O_3-TiO_2 are shown, the compounds located within the area of Quartz (Tridymite- Cristobalite), Mullite and Fe-Spinel and for other located within the area of Mullite, Cristobalite and Tialite [16]. These results are in good accordance with XRD patterns which are shown in Fig. 5 and 6.

Bulk density study

In refractory systems with ceramic (chemical) bonding, density and porosity are dependent on particle size distribution, density of each component, also, sintering process and reactions which is accompanied by volume expansions [17]. As shown in Fig.7, bulk density changing in the samples, it is observed, all of samples are non-density body. So, porosity is important for production of the lightweight insulation panel. These results are in good accordance with sintering shrinkage percent diagram and by SEM images of sample P30 after sintering at a) 900 °C and b) 1100 °C which are shown in Fig.8 and 9.it is observed that microstructure is fills pores of various sizes as well as expanded perlite.

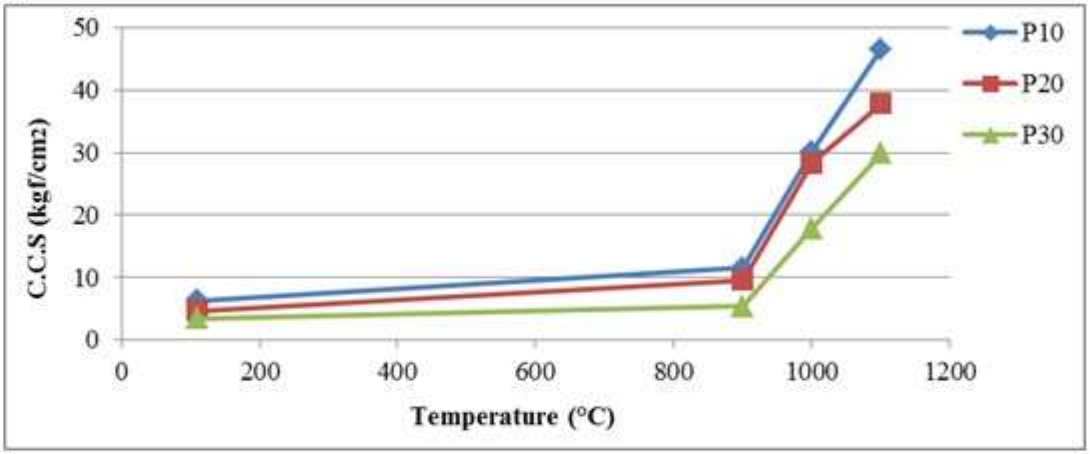


Fig.2, the effect of temperature on cold crashing strength in samples

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

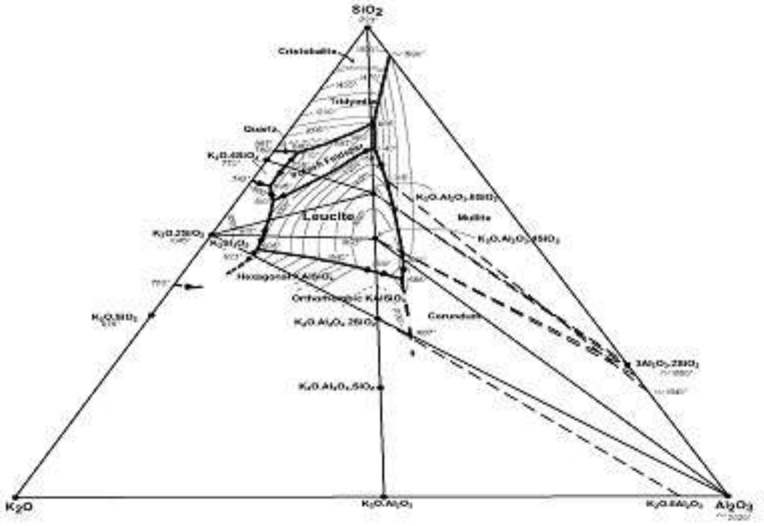
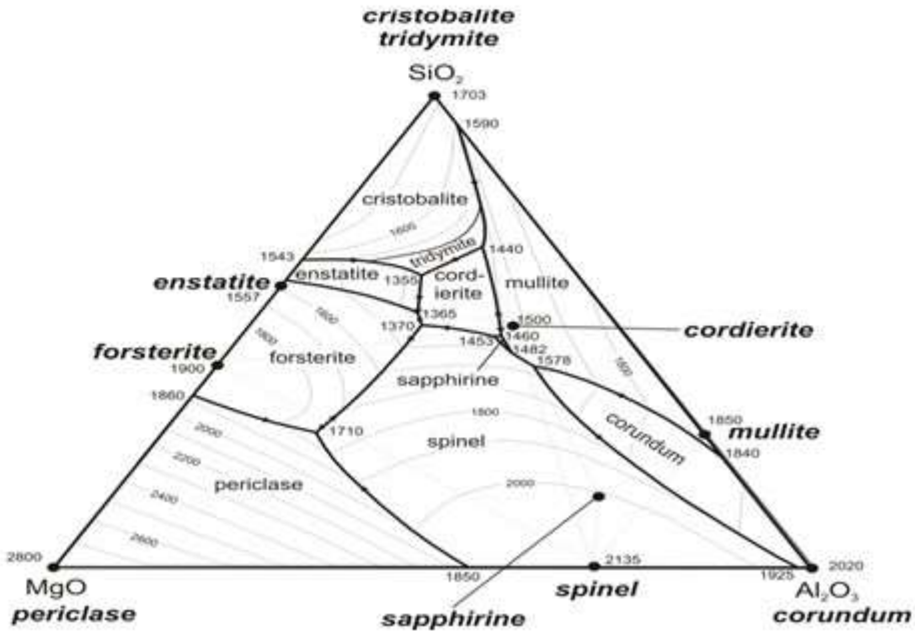


Fig.3, the equilibrium diagram on ternary system of SiO_2-Al_2O_3-K_2O

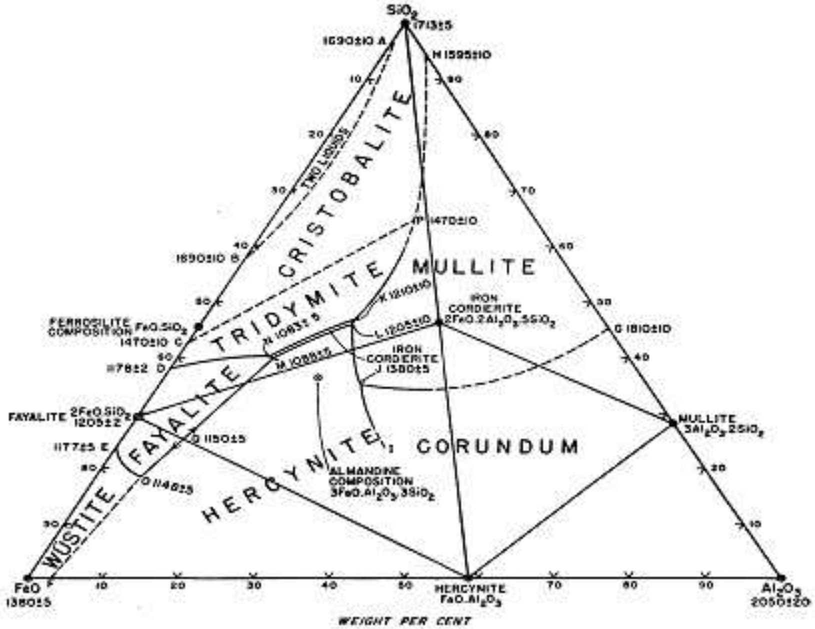
INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

a

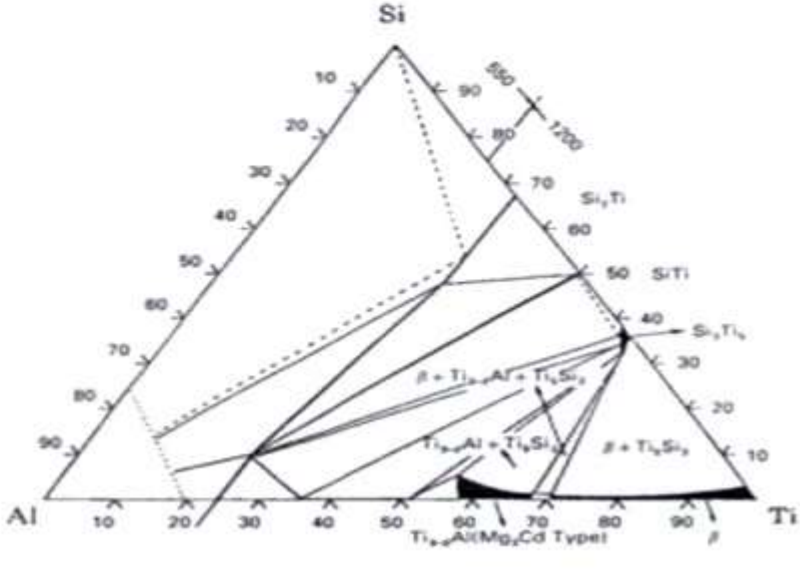


INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

b



c



INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

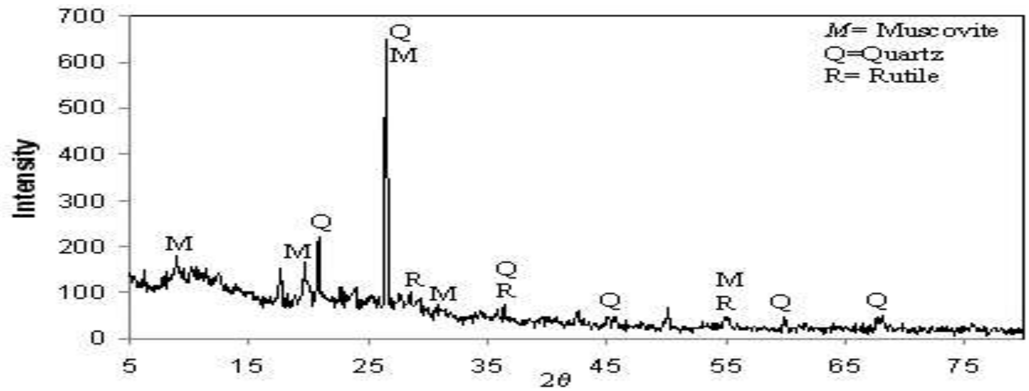


Fig.*4*, equilibrium diagram on ternary system of a) SiO_2-Al_2O_3-MgO, b) SiO_2-Al_2O_3-FeO(Fe_2O_3) and c) SiO_2-Al_2O_3-TiO_2

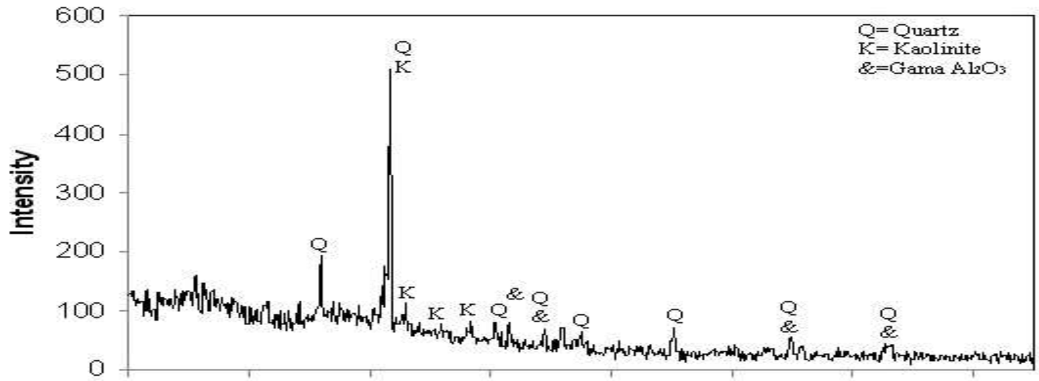


Fig.*5*, X-ray diffraction pattern of the sample P30 after sintering at 900 °C

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

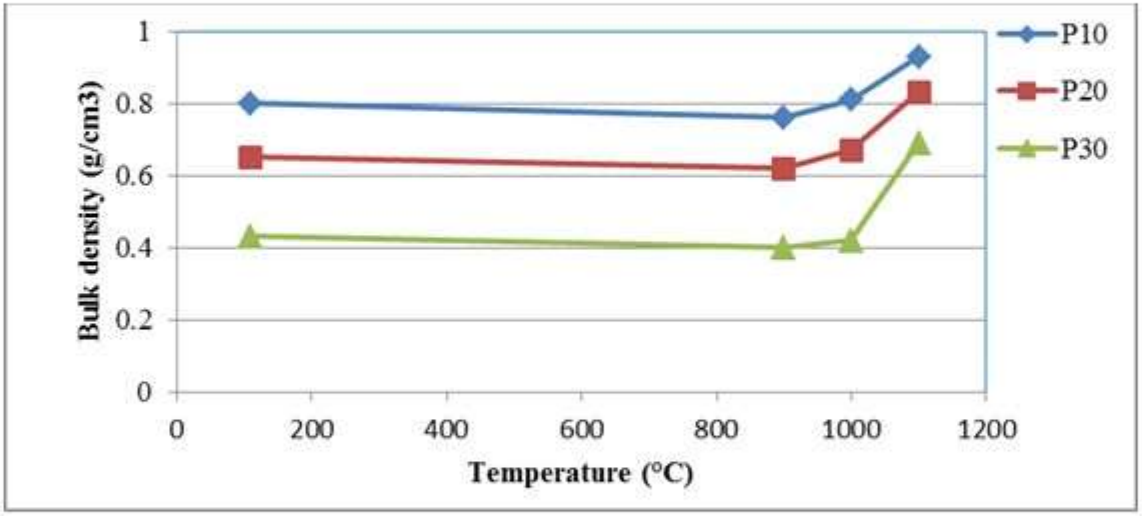


Fig.6, X-ray diffraction pattern of the sample P30 after sintering at 1100 °

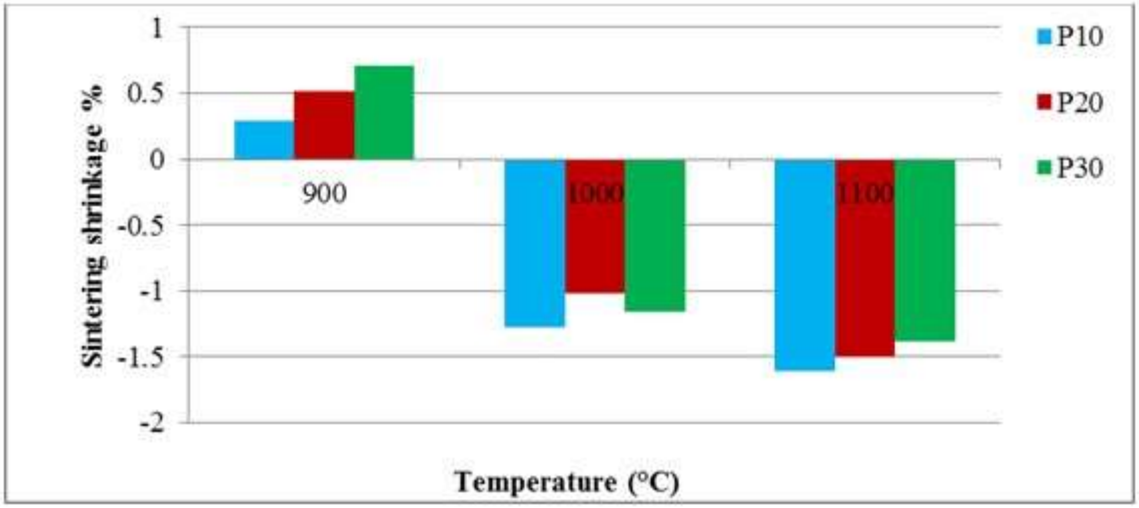


Fig.7, bulk density changing in the samples

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

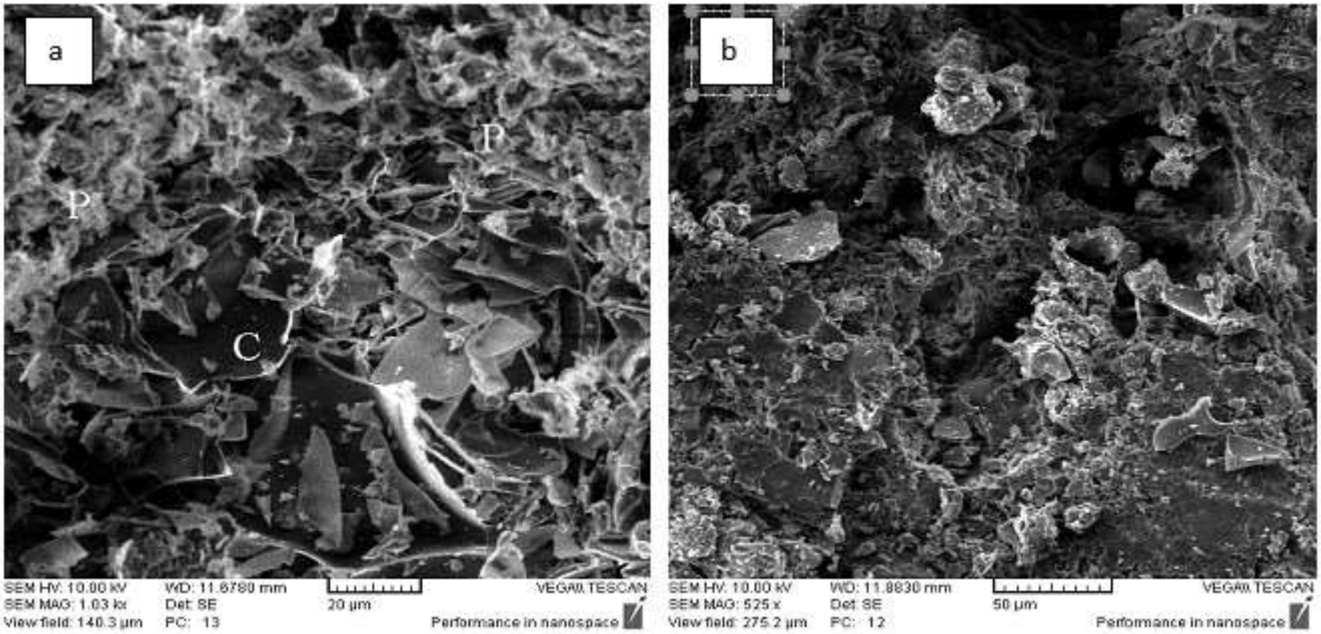


Fig. 8, Sintering shrinkage % of the samples

Fig. 9, SEM morphology of P30 after sintering at a) 900 °C and b) 1100 °C

Permanent linear change study

This test is very important in functional conditionbecause is a measure for assessing the application temperature. Fig. 10, shows the permanent linear change (PLC) diagram of the samples. The samples which sintered at 900 °C are not capable of operating at this temperature.For resolving this problem, need to increase the sintering time or temperature.Permanent changes occur due to the continuation of the sintering process and phase transformations or different reactions. Balclay phase transformation containing kaolinite, pyrophyllite, Muscovite, Illite, Hematite and Anatase is not complete. Also, there is a possibility of crystallization of silica with increasing the sintering time.

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

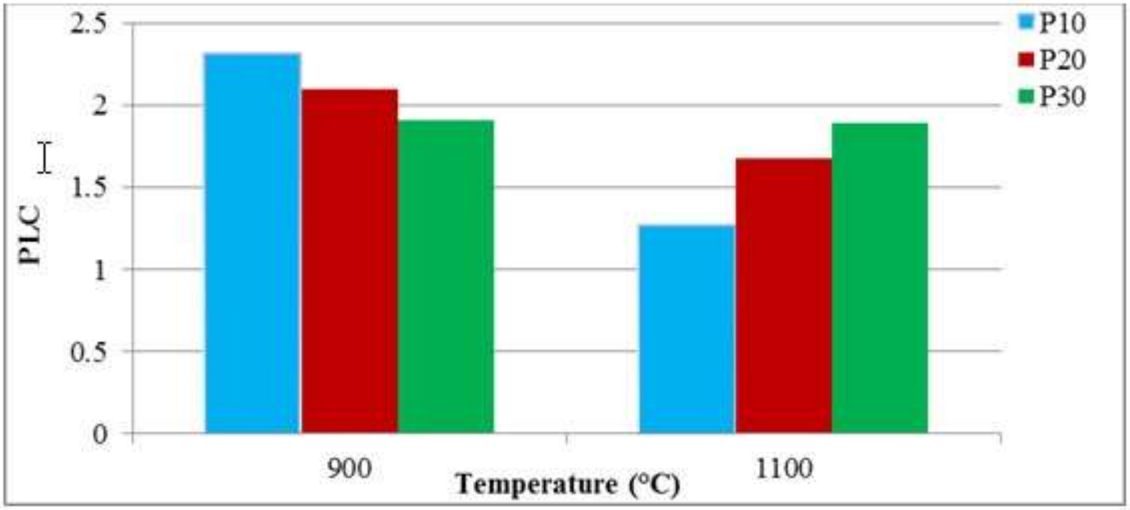


Fig.10, The permanent linear change (PLC) of samples

Conclusions

The lightweight refractory insulation panels on the basis of Perlite with chemical bonding (H_3PO_4) were successfully prepared by Extruding technique. Sintering behavior is the key to achieve the right balance between the low final density, which is the basis for good thermal insulation properties, and good mechanical properties and durability, achieved only by allowing the material to reach the right sintering temperature. Mullite phase has been improved microstructure of the panels. Because the amount of PLC is less than of 2 %, So, this refractory panel has not problem for applying in kiln wall. This panel can save energy that always escaped from inside of the industrial furnaces.

References

1. Krishna BhavaniSiramK.:Cellular Light-Weight Concrete Blocks as a Replacement of Burnt Clay Bricks., International Journal of Engineering and Advanced Technology. Vol 2(2). pp.149-151 (2012)
2. Lin, P.I.: Perlite and vermiculite, Industrial Minerals. 1998, pp. 55-58.
3. Banerjee, S.: Monolithic Refractories A Comprehensive Handbook. World Scientific Publishing. 1998, pp. 33-34.
4. Gonzales otero, J.; Blanco, F.; Gorcia, P.; Ayala, J.: Manufactore of refractory insulating bricks using fly ash and day. british ceramic transactions.vol.103(4), pp.181-186 (2004).
5. Kogel, J.E.; Trivedi, N.C.; Barker, J.M.: Industrial Minerals & Rocks: Commodities,Markets, and Uses. 2006, pp. 685-703 and 1153-1179.
6. Chester, J.H.: Refractories, Production and properties. The Iron and steel Institute, 1973.pp.401-421.
7. Pichór, W.; Janiec, A.:Thermal stability of expanded perlite modified by mullite, Ceramics International. Vol 35(1), pp. 527-530 (2009).

INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT

8. Subramanian, R.B.; Machhoyo, B.B.; Savasani, R.M.; Maiti, K.N.: Properties of hot-face insulation bricks by foaming. Interceram. 1996, Vol.45(4).
9. Calacal, E.L.; Whittemore, O.J.: The sintering of Diatomite. Am.ceram. soc.Bull.66(5),1987, pp. 790-793.
10. Fragoulis, D.; Stamatakis, M.G.; Chaniotakis, E.; Clumbus. G.: Materials characterization. 2004, pp. 307-316.
11. Schacht, C.A .; Refractories Handbook, Marcel Dekker Inc. New York. 2004, pp. 215-257.
12. lkerBekirTopc, Burak Is-ıkdag.: Manufacture of high heat conductivity resistant clay bricks containing perlite, Building and Environment 42, pp. 3540–3546 (2007).
13. Pimraksa, K.; Chindaprasirt, P.: Lightweight bricks made of diatomaceous earth, lime and gypsum, Ceramics International. Vol. 35(1), pp. 471-478 (2009).
14. Marghussian, V. K.; Naghizadeh, R.: Chemical bonding of silicon Carbide Journal of the European Ceramic Society. Vol.19(16), pp. 2815-2821 (1999).
15. Ghanbarnezhad, S.; Nemati, A.; Bavand-Vandchali, M.; Naghizadeh, R.: New development of spinel bonded chrome-free basic brick. Journal of Chemical Engineering and Materials Science. Vol. 4(1), pp. 7-12 (2013).
16. http://www.crct.polymtl.ca
17. Ghanbarnezhad, S.; Nemati, A.; Bavand-Vandchali, M.; Naghizadeh, R.: Effect of TiO2 in Spinel Formation and Reactive sintering of Magnesia-rich Ceramics. International Journal of Engineering and Advanced Technology. Vol 2(3), pp.85-87 (2013).