NUEJ
NARESUAN UNIVERSITY
ENGINEERING JOURNAL

A Potential of Vetiver Grass for Feldspar Replacement in Ceramic Processing

A. Nakaruk[1,2,*], T. Threrujirapapong[1,2], D. Channei[3], W. Khanitchaidecha[1,4]

[1]Centre of Excellence for Innovation and Technology for Water Treatment
[2]Department of Industrial Engineering, Faculty of Engineering
[3]Department of Chemistry, Faculty of Science
[4]Department of Civil Engineering, Faculty of Engineering
Naresuan University, Phitsanulok 65000, Thailand
* Corresponding authors: auppathamn@nu.ac.th

Abstract - **Vetiver grass is one of the most common grass in Thailand. It has been grown in many locations for land erosion prevention, toxic pollutants removal, and environmental remediation. The chemical analysis revealed that vetiver grass consisted of >50 % of K and ~20% of Si. This data suggested that the vetiver grass is possible to replace feldspar in ceramic processing. The thermal analysis of vetiver grass also confirmed that the vetiver grass can act as fluxing agents to form a glassy phase at low temperatures (873 K). The effect of vetiver grass on feldspar replacement on some properties of ceramics were investigated such as density, porosity, and bending stress. The results showed that with increasing the ratio of vetiver grass the density of sample decreased from 2.20 g/cm^3 (100% of feldspar) to 1.91 g/cm^3 (100% vetiver grass). The explanation is that during the firing process vetiver grass can generate CO_2 from hydrocarbon decomposition, this CO_2 created pores inside the sample, then the density was decreased. On the other hands, the bending stress decreased from 12.85 MPa (100% feldspar) to 9.07 MPa (100% vetiver grass). In conclusion, the results proved that the vetiver grass is a good candidate to replace feldspar in ceramic processing. This means it can be one option for promoting environmental sustainability in term of waste and mining reductions.**

Keywords – vetiver grass, feldspar, ceramic processing

1. Introduction

Feldspar is one of the key materials for ceramic and grass processing, it acts as fluxing agents to form a glassy phase at low temperatures. Further, it also enhances the strength and durability of the ceramics body. Basically, there are three types of feldspar including, Albite ($NaAlSi_2O_8$), Anorthite ($CaAl_2Si_2O_8$), and Orthoclase ($KAlSi_3O_8$). However, in order to obtain feldspar, mining is needed. It is known to cause environmental pollution. This leads to the reduction of feldspar mining in several countries. Therefore, finding the alternative materials for feldspar replacement has become an important issue. Vetiver grass is one the most common plant in Thailand. Thai government encourages farmer and people in the remote area to grow up the vetiver grass because it can be used in many applications including, land erosion prevention, and embankment stabilization [1, 2]. Recently, the state of the art literatures indicated that the vetiver grass can be used in environmental remediation applications such as removal of polycyclic aromatic hydrocarbons (PAHs) [3], and persistent organic pollutants (PoPs) [4].

In the previous work by the authors [5], the chemical analysis of vetiver grass revealed that potassium (K) and silicon (Si) are the main elements. This data suggested that it has main elements similar to feldspar. Then, this work presented the possibility of use of vetiver grass as feldspar in ceramic processing.

2. Methodology

The fresh vetiver grass was corrected from the crop field in Phitsanulok province, Thailand. It was dried at 378 K for 12 h to remove the moisture. The dried vetiver grass was cut into small peace and blend using commercial blender for 10 min. Afterwards, it was mixed with the feldspar (local supply) with different ratio of feldspar/vetiver grass (100/0, 80/20, 60/40, 40/60, 20/80 and to 0/100 in weight ratio). The red clay (local supply) was dried at 378 K for 12 h, followed by ball milling for 12 h. Subsequently, the clay was mixed with 20% of water and 2% of feldspar (and/or vetiver grass), followed by pressing to form the bar shape.

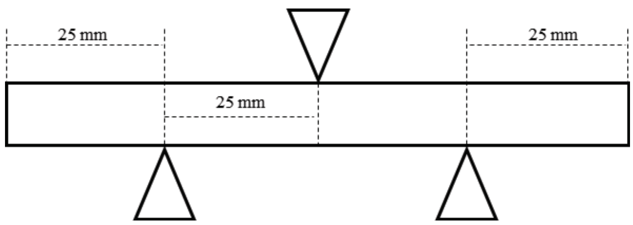


Figure 1. The loading geometry of 3-point bending

The X-ray fluorescence (XRF) was used to obtain the chemical composition of dried vetiver grass. In addition, the thermal analysis of the vetiver grass was done using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The samples were fired in the muffle furnace at 873 K for 12 h with 5 K/min of heating rate, followed by natural cooling. The density of samples was examined using Archimedes technique. The bending stress was evaluated using 3-point bending method with 100 mm x 20 mm x 5 mm (length x width x height) of sample dimension. The loading geometry of 3-point bending is shown in Figure 1. The strain rate of loading was controlled at 0.1 mm/min.

3. Results and Discussion

The data reveal that the dried vetiver grass contained 57 wt% of K, 20 wt% of Si, 9 wt% of Ca, 7 wt% of Cl, 3 wt% of S, 2 wt% of P, and 1.5 wt% of Fe by weight. These data is similar to other the previous work [5] and other literature review [6]. Figure 2 shows the TGA/DSC curves of dried vetiver grass. The data indicates weight loss at temperature ~373 K, this refers to the removal of physically adsorbed water in the vetiver grass. In addition, another main weight loss during 773 K to 873 K can be the dehydroxylation process of the remaining minerals [7, 8]. The DSC curve also indicates the exothermic peak at ~873 K, this phenomenon suggests the flux forming of the vetiver grass. It can be said that the vetiver grass start melting to form the crystalline phase at ~873 K, then it can acts as an agent to form a glassy phase in ceramic firing process.

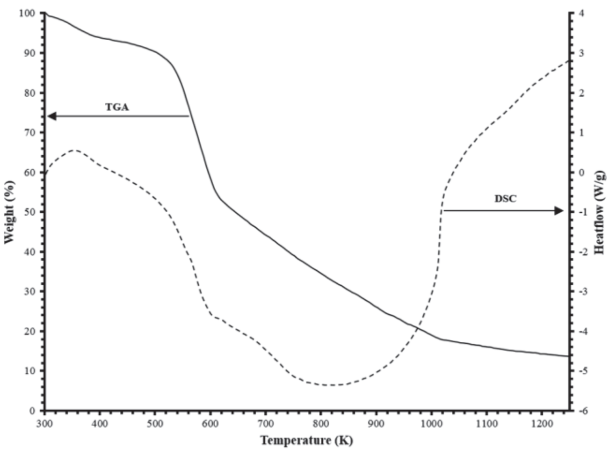


Figure 2. Thermal Analysis of dried vetiver grass

Table 1. The analytical data of samples

Sample (Feldspar/Vetiver grass)	length (mm)		Density (g/cm^3)	Bending Stress (MPa)
	Before Firing	After Firing		
100/0	104	96	2.09	12.85
80/20	105	95	2.06	10.67
60/40	104	95	2.03	10.32
40/60	103	95	2.00	9.80
20/80	104	96	1.96	9.46
0/100	104	96	1.94	9.07

Table 1 shows the analytical data of samples. It can be seen that there is no effect of vetiver grass on firing shrinkage of the samples. There is ~7% of firing shrinkage for all samples. The density of the samples slightly decreased with increasing the ratio of vetiver grass/feldspar. In addition, the bending stress of the samples is shown in the Figure 3. It indicates that the bending stress decreased significantly with increasing the vetiver grass ratio.

The explanation is that the hydrocarbon decomposition occurred at 473 K to 573 K of firing temperature, as shown in Figure 1 [9, 10]. The hydrocarbon decomposition is known to generate CO_2, then it will create pores inside the sample. Therefore, the sample contained high vetiver grass should have high porosity and low density. Figure 4 shows the cross section image of the samples. It can been seen that the sample contained 100% of vetiver grass seems to have higher porosity than the sample contained 100% of feldspar.

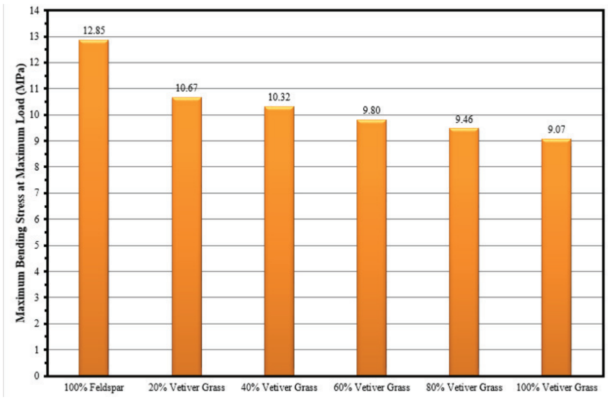
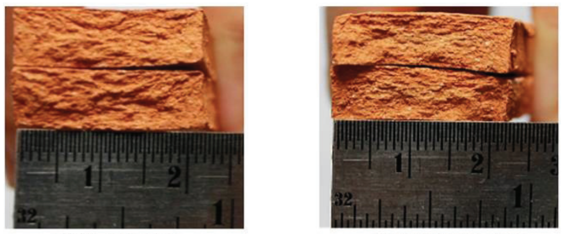


Figure 3. Bending stress of the sample



100% Feldspar   100% Vetiver grass

Figure 4. Cross section image of the sample

4. Conclusions

The present work proves that there is a great possibility of using vetiver grass as feldspar replacement. Especially, the thermal analysis strongly suggested that the vetiver grass can act as fluxing agents, resulting to form glassy phase at 600 °C. The results suggest that the sample contained vetiver grass had high porosity and low density compare to the sample contained feldspar. However, the bending stress of sample decreased with increasing vetiver grass/feldspar ratios. It has to be noted that the sample contained vetiver grass is low density and light weight then it is very suitable to be used as construction materials (*i.e.* wall and tie), porcelain, and stoneware. In conclusion, the results proved that the vetiver grass is a good candidate to replace feldspar in ceramic processing. This means it can be one option for promoting environmental sustainability in term of waste and feldspar mining reductions.

5. Acknowledgement

The authors would like to thank Naresuan University's research funding for the financial support.

6. References

[1.] S.O. Oshunsanya. "Spacing effects of vetiver grass (Vetiveria nigritana Stapf) hedgerows on soil accumulation and yields of maize–cassava intercropping system in Southwest Nigeria", Catena, vol. 104, pp. 120–126, 2013

[2.] N.O.Z. Abaga, S. Dousset, S. Mbengue, and C. Munier-Lamy. "Is vetiver grass of interest for the remediation of Cu and Cd to protect marketing gardens in Burkina Faso", Chemosphere, vol. 113, pp. 42–47, 2014.

[3.] K.C. Makris, K.M. Shakya, R. Datta, D. Sarkar, and D. Pachanoor. "High uptake of 2, 4, 6-trinitrotoluene by vetiver grass – Potential for phytoremediation?", Environ. Pollut., vol. 146, pp. 1–4, 2007.

[4.] M. Ye, M. Sun, Z. Liu, N. Ni, Y. Chen, C. Gu, F.O. Kengara, H. Li, and X. Jiang. "Evaluation of enhanced soil washing process and phytoremediation with maize oil, carboxymethyl-b-cyclodextrin, and vetiver grass for the recovery of organochlorine pesticides and heavy metals from a pesticide factory site", J. Environ. Manage., vol. 141, vol. 161–168, 2014.

[5.] S.T.T. Le, N. Yuangpho, T. Threrujirapapong, W. Khanitchaidecha, and A. Nakaruk. "Synthesis of mesoporous materials from vetiver grass for wastewater treatment", J. Aust. Ceram. Soc., vol. 51, vol. 40–44. 2015,

[6.] P. Methacanon, O. Chaikumpollert, P. Thavorniti, and K. Suchiva. "Hemicellulosic polymer from Vetiver grass and its physicochemical properties", Carbohydr. Polym., vol. 54, pp. 335–342, 2003.

[7.] S.Kr. Das and K. Dana. "Differences in densification behaviour of K- and Na-feldspar-containing porcelain bodies", Thermochim. Acta, vol. 406, pp. 199–206, 2003.

[8.] L. Vaculíková and E. Plevová. "Identification of clay minerals and micas in sedimentary rocks", Acta Geodyn. Geomater., vol. 138, pp. 167–175, 2005.

[9.] P.T. Williams and Serpil Besler. "The influence of temperature and heating rate on the slow pyrolysis of biomass", Renew. Energ., vol. 7, pp. 233–250, 1996.

[10.] U.Domanska."Thermophysical properties and thermodynamic phase behavior of ionic liquids", Thermochim. Acta., vol. 448, pp. 19–30, 2006