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Korat Special Clay

D. Jentavorn, S. Srinoikhao, J. Sukontasawath, and C. Lorprayoon

School of Ceramic Engineering, Suranaree University of Technology, Nakorn Ratchasima 30000, Thailand

ABSTRACT

In searching for clay used in ceramic industry, the clay has to be characterized and heat-treated. The evaluated results will indicate its application. In this study, Korat clay depositing at Suranaree University of Technology (SUT) was collected and divided into three groups; i.e. white clay, reddish brown clay, and the mixture of the two types. All of them were washed through 150 mesh sieve and dried prior to characterization. To study the behaviour under heat-treatment, only the mixed clay was fabricated into test bars and fired at 600 – 1,200 C. From our study, these clays changed their colors to brown after firing at 1,200 C due to iron oxide content (2.63 % for the white and 5.98 % for the reddish brown clay). The glassy phase was found after heat-treatment at 1,100 C. The highest fired density of the mixed clays was 2.12 g/cm^3. Its compressive strength and bending strength were 173 ± 2.0 MPa and 59 ± 1.8 MPa respectively. When the temperature was increased to 1,200 C, the density decreased to 1.18 ± 0.04 g/cm^3 and the strength decreased to 44 ± 2.2 MPa and 15 ± 1.1 MPa for the compressive and bending tests. The clay linearly expanded 53 % corresponding to 40 % porosity at 1,200 C. The product exhibiting these characteristics after high temperature heat-treatment is very promising for light weight aggregate production to be used in light weight concrete, light weight brick or as filter aids.

Key words : Korat clay, Lightweight aggregate

INTRODUCTION

Various white clays always are of ceramist's interest because they are basic raw material in ceramic industries such as whitewares, sanitarywares etc. If their particle sizes are fine enough their applications even go further for the paper industry as paper coating, or as filter aids in oil and cosmetics, etc. The existing white clay layer located about 1-2 feet beneath the surface clay at SUT was quite attractive. This clay was located about 20 km away from Dan Kwain pottery clay in Chok Chai District. It was investigated to determine if this clay had any special characteristics as compared to that of Dan Kwain. Therefore the aim of this study was to characterize the clay in terms of chemical and particle size analyses, phases present and also the behaviour under heat- treatment concerning thermal phase transformations, changing in density, porosity and mechanical properties of the fired product affected by temperatures. The understanding of the clay's characteristics will therefore determine its applicability.

MATERIALS AND METHODS

The studies were made on three types of the clay selected by visual separation into the white and reddish brown and the mixture of the two types. Each clay was dry ground in a Fritsch jaw crusher and disc mill and washed in a lab blunger. When coarse particles settled down, fine clay slurry was screened through a 150 mesh sieve, and dried 24 hours at 100 °C. Two types of samples were prepared namely powder for characterization and cylindrical bars for sintering and mechanical testing. The cylindrical bars , 160 mm and 26 mm in length, were prepared by extrusion through 13 mm die and dried.

Characterization

The Department of the Mineral Resources performed the wet chemical analysis, the Ministry of Industry. The particle size analysis were determined using sieve method and sedimentation (centrifugal particle size analyser SA-CP2). To establish the identity of the phases present in Korat clay, a Philip powder x-ray diffractometer (XRD) with copper radiation and nickel filter was used together with an x-ray diffraction D5005 Bruker AXS.

Thermal Behaviour

Thermogravimetric analysis (TGA) and differential thermal analysis (DTA) were made. Clay samples were heated in platinum container in air at the rate of 10 C/min. from room temperature to 1000 °C using Dupont 2950 and 2910-1600.

Sintering and Heat-treatment

The mixed clay specimens were fired in an electric furnace at the rate of 10 C/min. The maximum

temperatures were between 600-1200 C. All of them were cooled to room temperature in the furnace.

Characteristics and Mechanical Tests.

Density and porosity were determined by Achimedes method, ASTM Designation C373-72 (Reapproved 1982). The observation of microstructure was done through a scanning electron microscope (SEM), Jeol JSM 6400. Five cylindrical specimens (13 mm in diameter and 160 mm in length) were selected for the 3-point bending test (401 NETZSCH model Geratebzu) using 110 mm span length. For the compressive strength test, the length of the cylindrical specimens was 26 mm and the compressive strength (digital load meter) Magnus international model no. 55R-2514 was used. A number of specimens was five for each test.

RESULTS AND DISCUSSION

Characteristics of the Clays

SUT clay had the principal chemical analyses as shown in Table 1. Phase analysis by XRD indicated that both white and reddish brown clays composed of low quartz, montmorillonite, orthoclase and potassium magnesium silicate (Fig. 1). The first three 2 θ and d-spacings having high intensities of each minerals and their chemical formula were in Table 2. The white clay had relatively lower iron oxide (2.63%) and higher magnesium oxide (4.01%) than the reddish brown which had 5.98% and 2.18% respectively . These Fe ions had to be in the chemical structures of those minerals because it was not found in the form of iron oxide by XRD analysis. According to Norton (1978), montmorillonite is a three-layer clay mineral and has very large ion exchange capacity.It always has small amount of iron, magnesium and potassium present within the crystal structure.

Thermal Study

TGA and DTA studies on SUT clays were in Figures 2 and 3. The white and the reddish brown had 7.3% and 6.4% total weight loss between 25 – 300 °C and 300 – 1000 °C, respectively.DTA curves showed a large peak between 25 – 300 °C which was doublet suggested by Green-Kelley (1952) that it was due to adsorbed water of montmorillonite ; one was due to hydration of the adsorbed ions in its layers and the other was due to direct adsorption. The removal of the OH- group seemed to occur at about 536 °C for the white and 563 °C for the reddish brown clay. A very small exothermic peak around 850 °C was due to crystallization.

The Mixed SUT Clay

The mixed clay classified by sieve analysis had 93.2% larger than 44 microns. Specimens under heat-treatment at various temperatures appeared in darker colors. Shrinkage and densification were observed in Figures. 4 and 5. When The temperature increased, the percentage of linear firing shrinkage increased up to 20.6 at 1100 °C. The bulk density gradually changed from 1.77 g/cm^3 to 2.12 g/cm^3 and reached the maximum indicating that densification finished at 1100 °C. Above 1100 C, the mixed clay altered its behaviour significantly. It expanded rapidly to 53.4%. The bulk density became 1.18 g/cm^3 and deformation took place. SUT clay composed of various associated clay minerals e.g. quartz, orthoclase and Potassium magnesium silicate. Under heat-treatment in

Table 1 Partial chemical analyses in SUT clay

Chemical Analysis	White SUT clay	Reddish brown SUT clay
Moisture	0.04	0.04
SiO_2	58.99	57.50
Al_2O_3	18.09	17.65
Fe_2O3	2.63	5.98
MgO	4.01	2.18
CaO	0.09	0.09
*LOI	6.12	4.80
Other	10.03	11.76

* LOI = loss on ignition

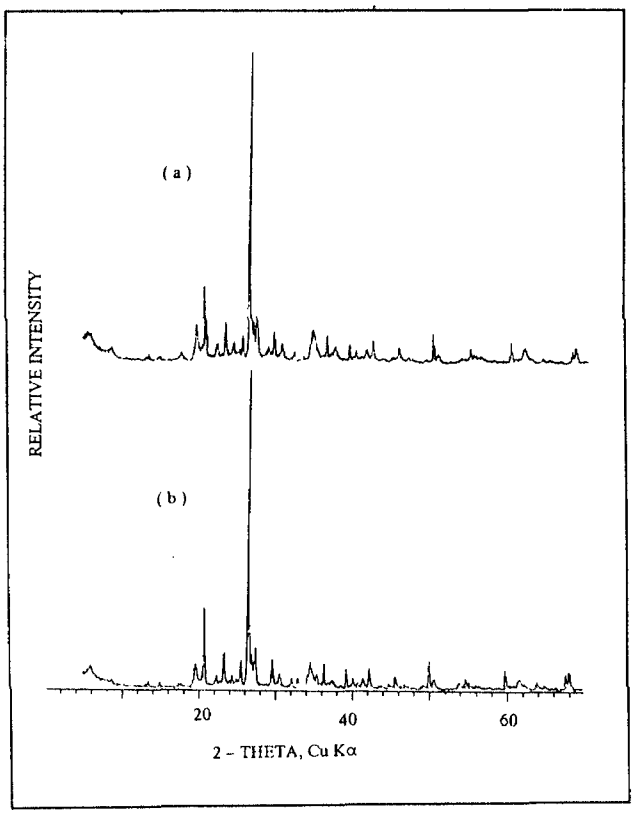


Figure 1 X-ray diffractograms
a. White SUT clay b. Reddish brown SUT clay

addition to dehydroxylation, quartz inversions followed by crystallization of the clay mass were observed in the DTA thermograms. Naturally orthoclase starts to form glass when heat to about 1100 °C. as the temperature increased the glassy phase increases and finally melting occurs. Manning (1995) mentioned that the firing behaviour of individual mineral components of clay, coarse fragments (such as quartz) survive the firing process relatively unchanged whereas others reacted rapidly. It was the truth in this experiment as shown in Figure 6 and Table 3. After heat treatment to 800 °C, the XRD patterns of mixed SUT clay looked the same as that of the room temperature one. Phase change was clearly observed after heat treatment at 1200 °C. The existing phases were only quartz of a low temperature form, glassy phase and a spinel phase (2θ: 31.2, 36.7, 44.6; d-spacing : 2.87, 2.45, 2.03). By running XRD test for the existing glassy phase, it was found that the 1100 °C and 1200 ° C XRD patterns exhibited halos peaking at around 2θ (Cu Kα) to a certain extent which indicated that amorphous product was coexistent as that found by Fukase et. al . (1996). According to Grim et. al. (1940), montmorillonite fired about 800 °C exhibited a formation of a spinel which finally dissolved in the glassy phase and crystallized out later as mullite. In this study, mullite was found only by SEM method as needle crystals. It was noted that the minerals associated in SUT clay had an important influence on the existing phases after heat-treatment.

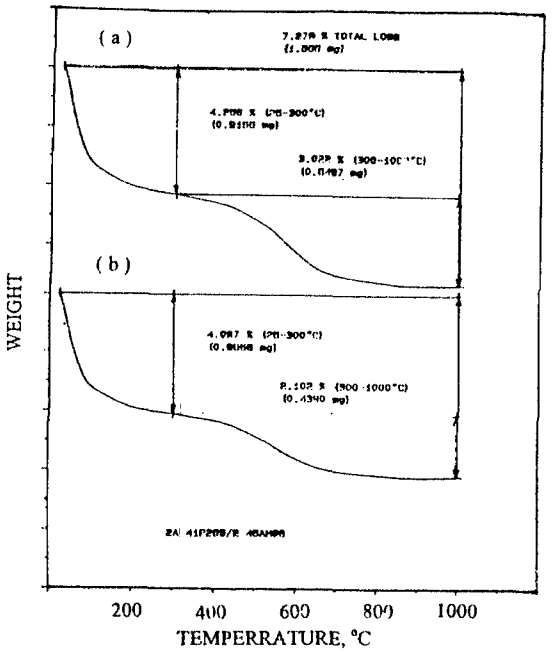


Figure 2 TGA thermograms of
a. White SUT clay b. Reddish brown SUT clay

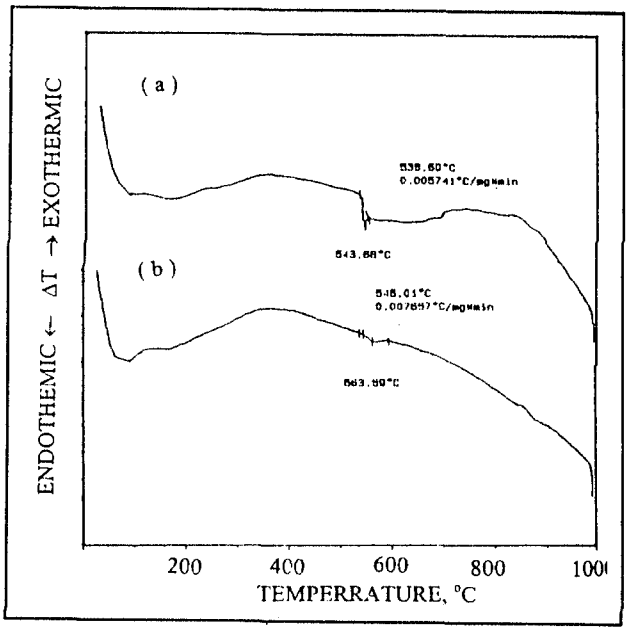


Figure 3 DTA thermograms of
a. White SUT clay b. Reddish brown SUT clay

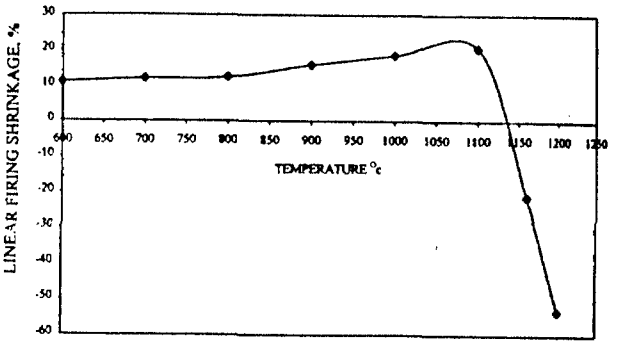


Figure 4 Linear firing shrinkage of mixed SUT clay

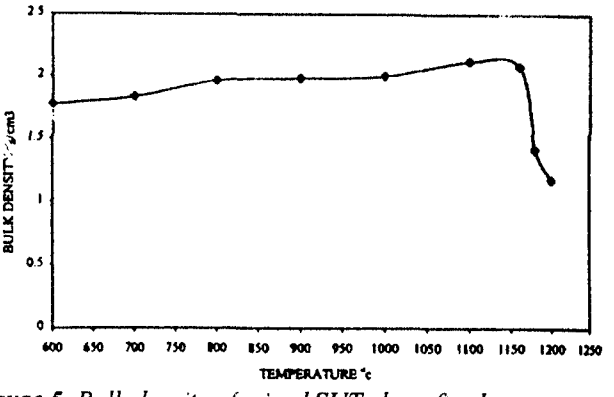


Figure 5 Bulk density of mixed SUT clay after heat-treatment

Table 2 Phases present in SUT clay

Phases Present	JCPDS	White SUT clay		Reddish brown SUT clay	
	d-spacing	2θ	d-spacing	2θ	d-spacing
Quartz, low	4.26	21.00	4.23	21.03	4.22
SiO2	3.34	26.77	3.33	26.97	3.30
	1.82	30.18	1.82	50.24	1.81
Montmorillonite	15.30	5.90	14.95	5.78	15.30
Si3.74, A12.03, Fe0.03	4.50	19.84	4.48	19.82	4.48
Mg0.22, O11	3.07	29.10	3.07	29.21	3.06
Orthoclase	4.22	21.00	4.23	21.03	4.22
KA1 Si3O8	3.77	23.52	3.78	23.52	3.78
	3.31	26.77	3.33	26.97	3.30
Potassium magnesium	3.35	26.77	3.33	26.97	3.30
Silicate	3.36	26.77	3.33	26.97	3.30
KMg2.5 Si4 O10 (OH)2	10.10	8.79	10.06	8.81	10.03

Table 3 Phases present in mixed SUT clay after heat-treatment

Temperature °C	Phases Present mixed SUT clay after heat-treatment
30	Quartz (low), Montmorillonite, Orthoclase and Potassium magnesium silicate
800	Quartz (low), Montmorillonite, Orthoclase and Potassium magnesium silicate
1200	Quartz (low), Spinel and Glassy phase

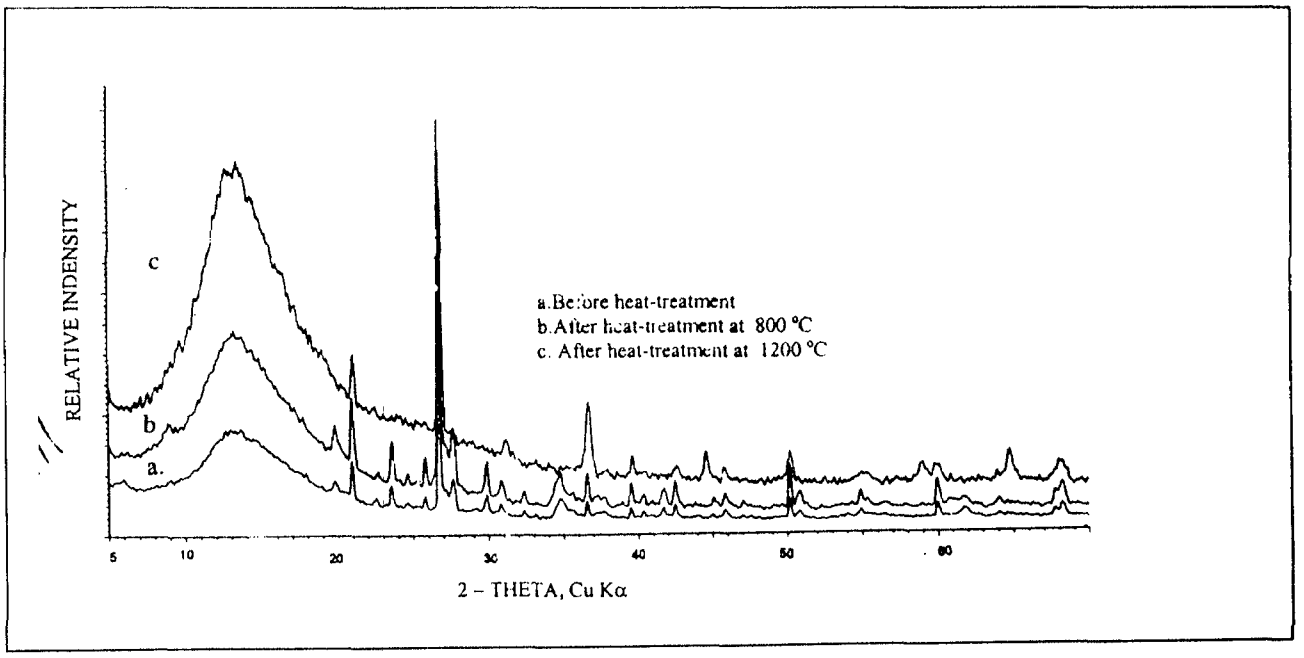


Figure 6 X-ray diffractograms of mixed clay

Porosity and Strength

Figure 7 illustrated the typical apparent porosity-temperature behaviour of the clay. As the temperature increased, the porosity decreased to the minimum (10.6%) at 1100 °C. Both bending and compressive strength (Figure 8 and 9) were increased to 59 ± 1.8 and 173 ± 2.0 MPa respectively, corresponding to the clay density (2.12 g/cm^3). Beyond 1100 °C, the clay was expanded by the high temperature phase change including the glassy phase. The strength decreased to 15 ± 1.1 and 44 ± 2.2 MPa after firing at 1200 °C. The evolution of gases under heat-treatment above 1100 °C was observed by the appearance of various sizes of pores in a bulk of the clay specimen as shown in Figure 10. The higher the temperature was, the larger the pore size became. During heating, the evolved gases (eg. water, .carbon dioxide or sulphur dioxide) escaped from the clay giving porous texture. The cause had not been yet investigated

In comparison to Dan Kwain pottery clay in Chok Chai District, Chumpol et.al (1978) reported that Dan Kwain clay composed of 75-80 % kaolinite and 20-25 % hydroxy aluminium interlayer vermiculite and a trace of Illite. After heating, its color turned to brown or orange brown, its water absorption decreased to between 1.0 – 5.5 % at 1200 °C and did not expand above 1100 °C. The phase present and thermal behaviour of the mixed SUT clay were different from Dan Kwain pottery clay.

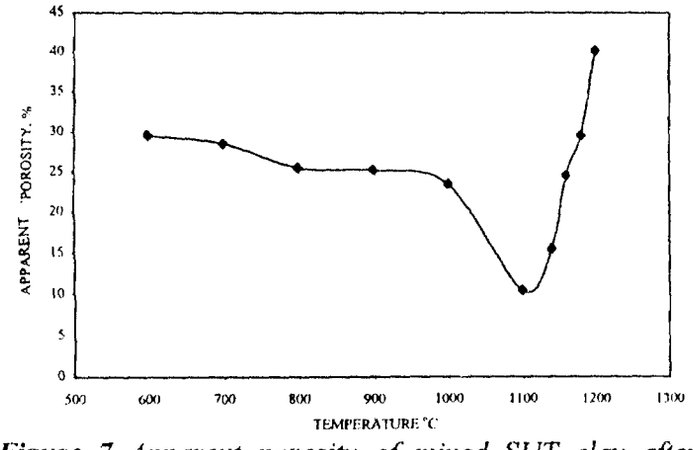
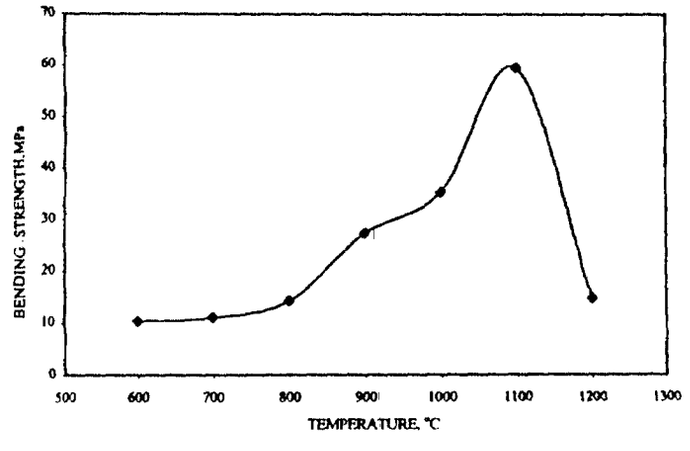


***Figure** 7 Apparent porosity of mixed SUT clay after heat-treatment*



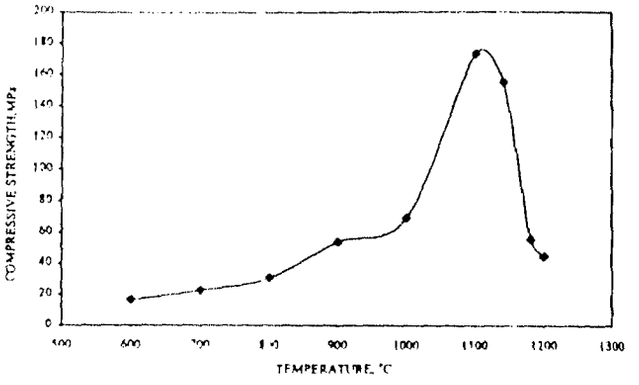


***Figure 9** Compressive strength of mixed SUT clay after heat-treatment*

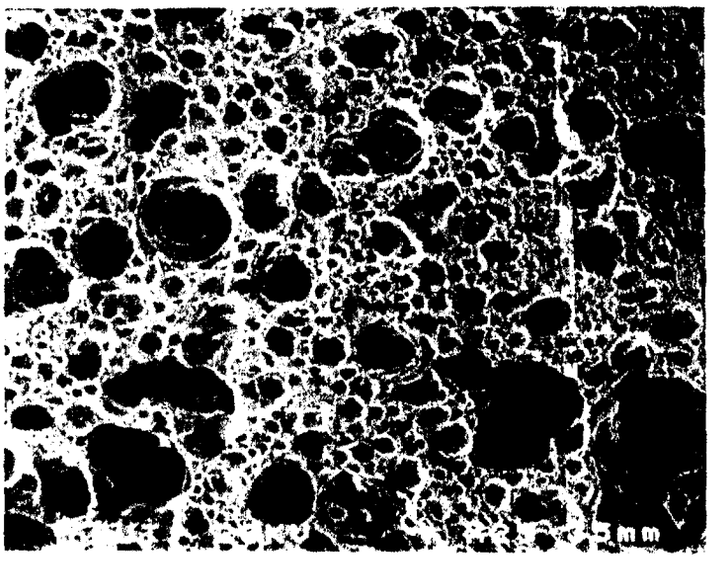


***Figure 10** Scanning electron micrograph of mixed SUT clay heat-treated at 1300 C*

CONCLUSION

Korat clay locating at SUT was the mixtures of montmorillonite, orthoclase, quartz and potasssium magnesium silicate. It occurred in the form of hard agglomerate of various sizes. The highest density was reached under heat treatment to 1100 °C due to dehydration and partial melting of the associated minerals. The clay capillaries were then filled with the glassy phase. If over firing, the color changed to dark brown with bloating effect caused by evolution of gases. The fired clay product contained numerous pores inside. All of these characteristics and behaviour of SUT clay are very promising for the production of light weight aggregate and filler aids.

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