

## CHAPTER 6

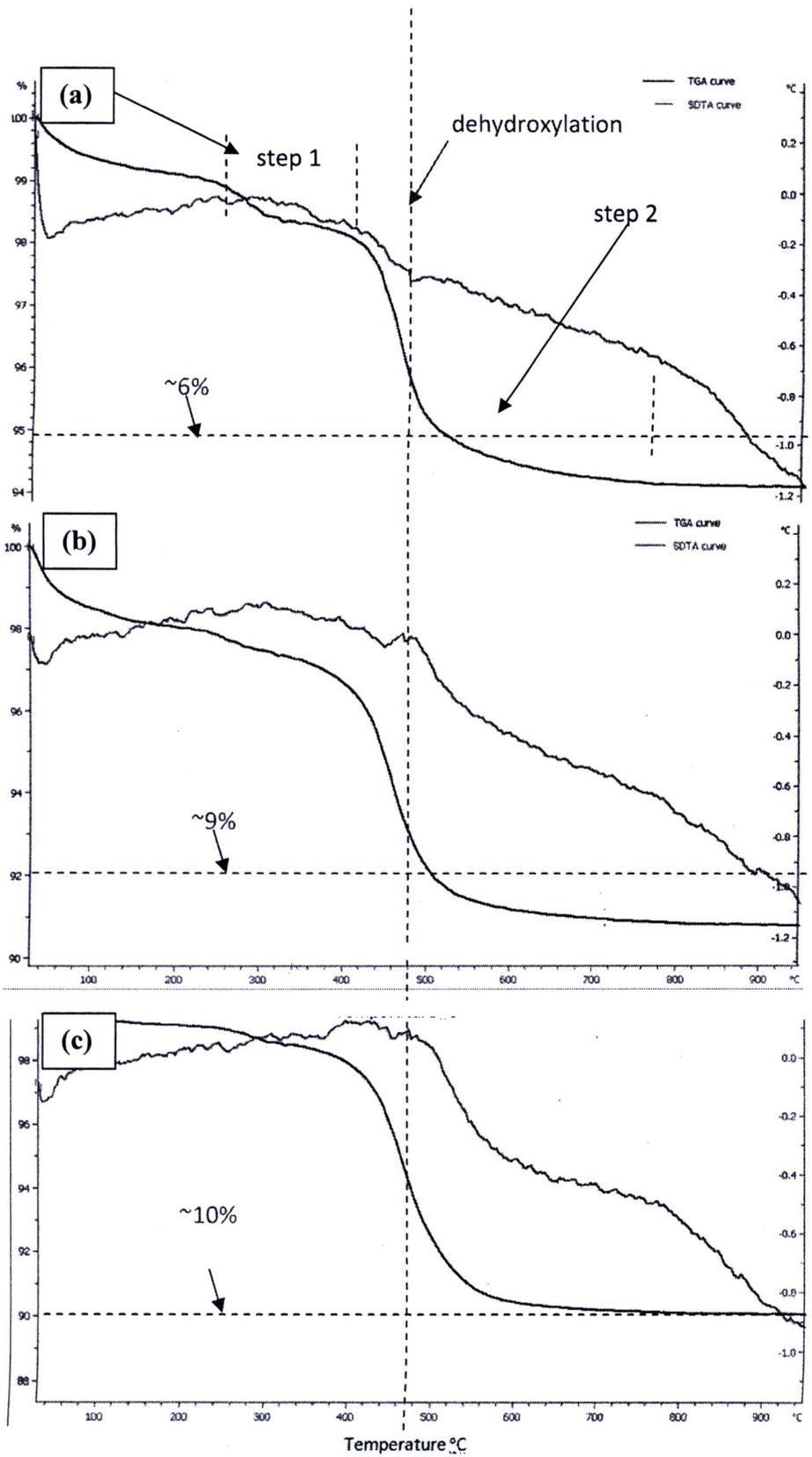
### RESULTS AND DISCUSSION (PART III):

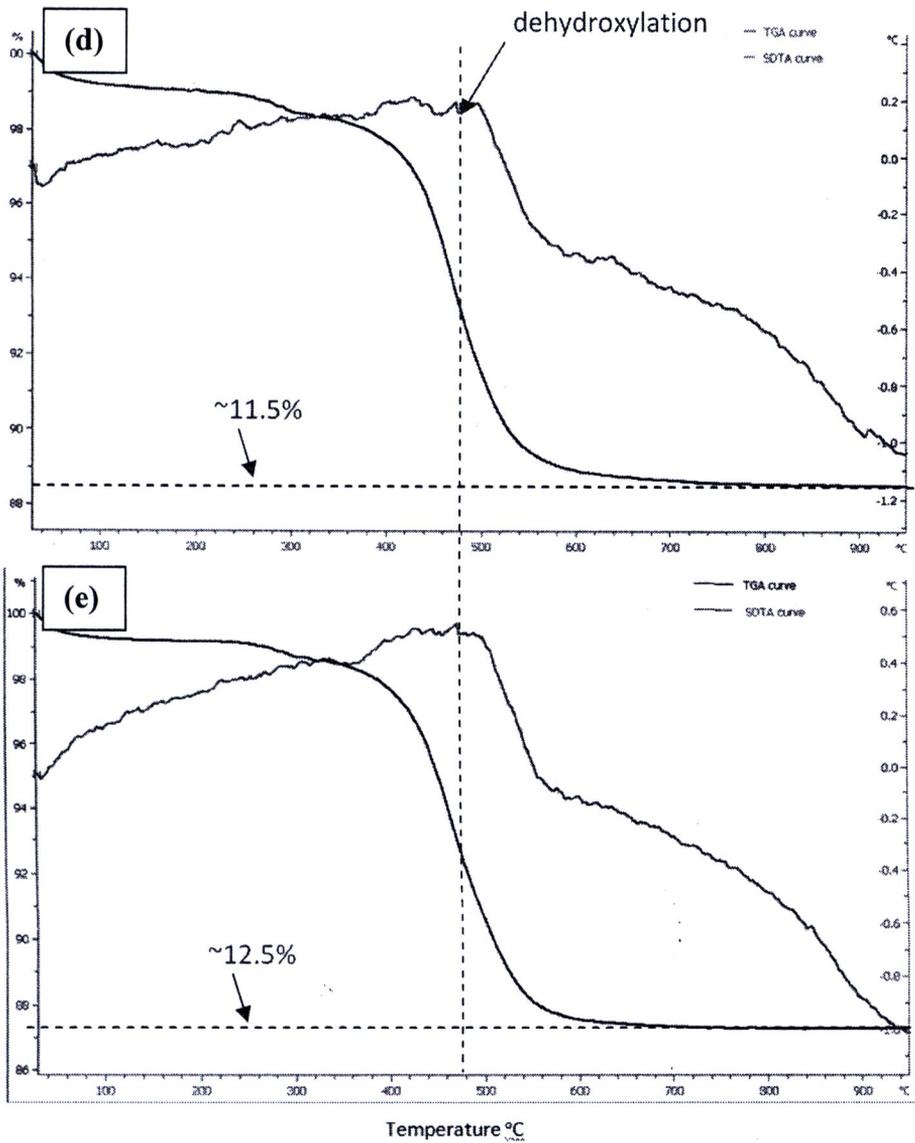
#### THERMAL CHARACTERIZATION OF FIRED TEST BRIQUETTES

In this chapter, the results of the investigation of thermal analysis are presented. The thermal analysis of the fired clay briquette briquettes was conducted on: namely, the thermogravimetric analysis, their coefficient of expansion and thermal conductivity.

##### 6.1 Thermogravimetric analysis (TGA/SDTA)

Thermal analysis of clay briquettes was carried out by using Mettler TGA/SDTA 851<sup>e</sup>. A specimen was heated at 3 °C/min under 50 ml/min air flow up to 950 °C. The briquettes were cooled down in the furnace to room temperature. Figures 6.1 a, b, c, d and e show the TG-DTA curves of briquettes mixed with charcoal (size 3) 0%, 2.5%, 5.0%, 7.5% and 10% by weight, respectively. Figure 6.1a shows the evaporation of physical water in the briquettes occurred at the temperatures between 50 and 100 °C [15]. Figures 6.1b and c display the beginning of burning observed at the temperatures 200-280 °C and 350-500 °C. This might be largely due to the burning of organic matter, charcoal and the removal of chemical water [16]. Figures. 6.1 b-e show briquettes mixed with charcoal in DTA curve; there was mainly one large exothermic reaction at the temperatures 300-500 °C corresponding to the burning of carbon in charcoal.





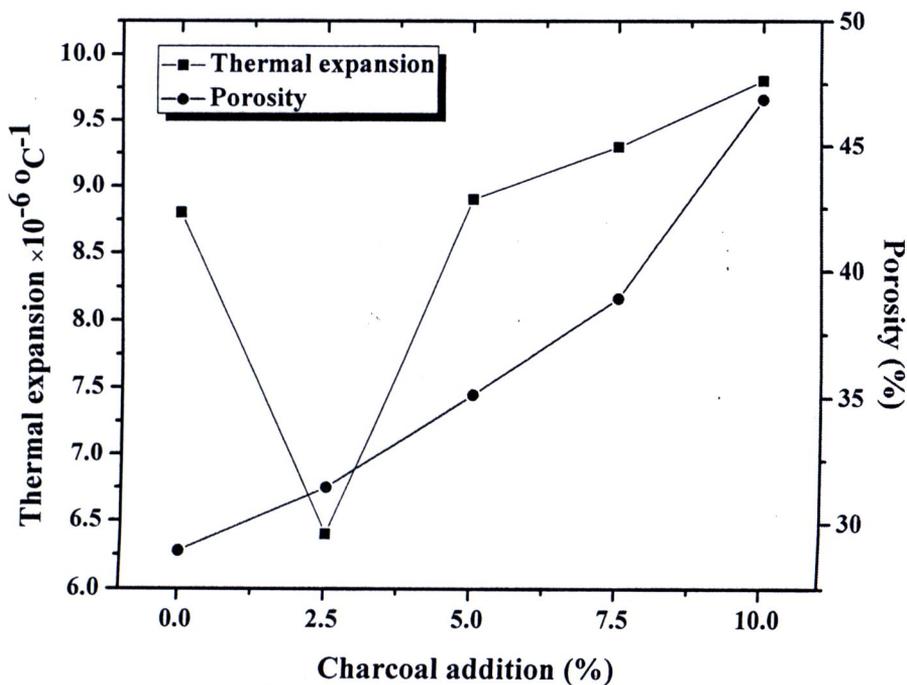
**Figure. 6.1** TG-DTA curved of briquettes with various amounts of charcoal: (a) Hang Dong clay without addition (b) 2.5%, (c) 5.0%, (d) 7.5% and (e) 10%.

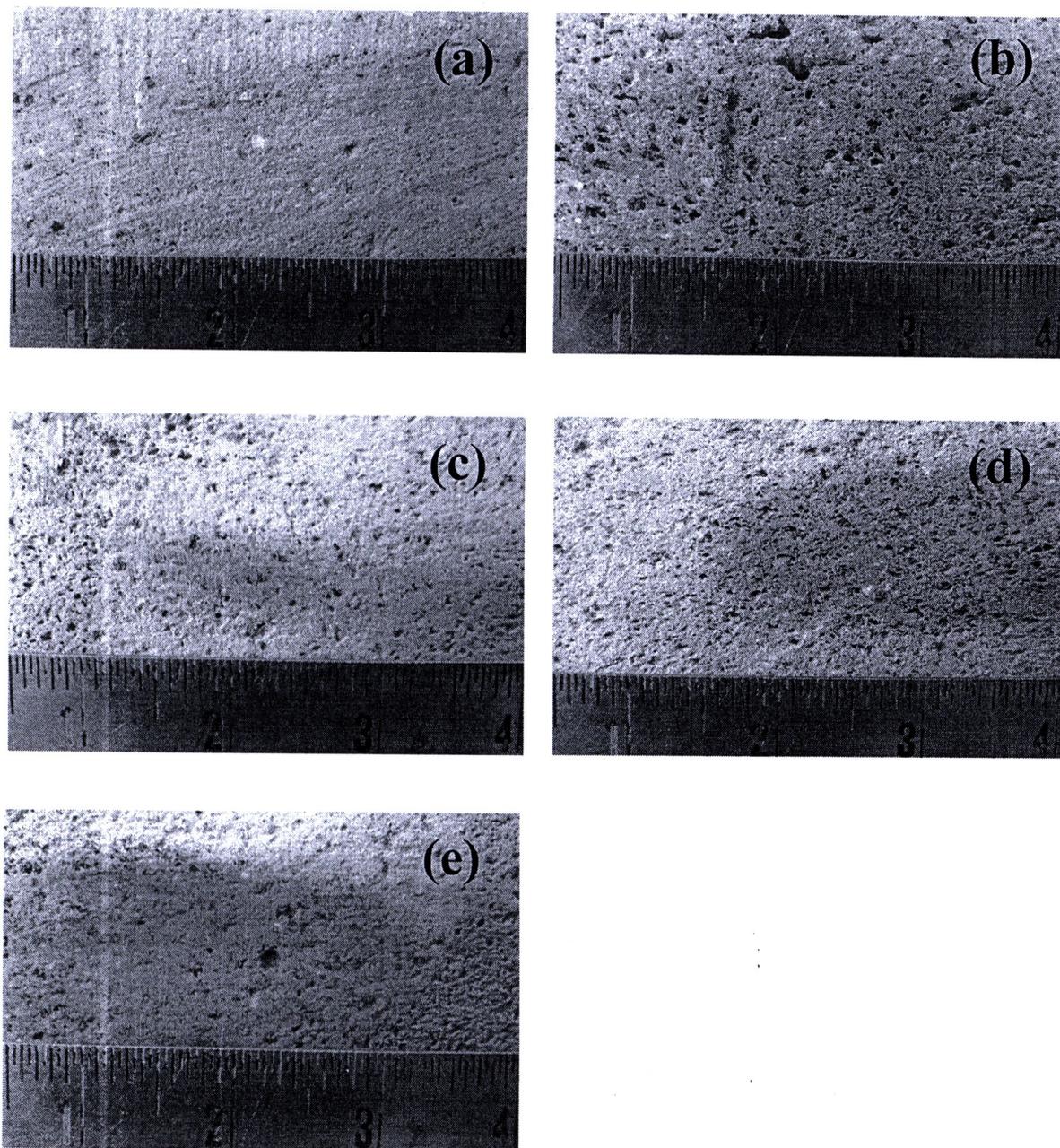
## 6.2 Coefficient of expansion analysis (COE)

Thermal expansion analysis was performed on test fired briquettes mixed with charcoal 0%, 2.5%, 5.0%, 7.5% and 10% (size 3) by weight and fired at 950 °C. The thermal expansion was calculated according to Eq. (3.1), when the briquettes were observed at the temperatures from 25-575 °C. The results indicated the thermal expansion in briquettes mixed with charcoal 0%, 2.5%, 5.0%, 7.5% and 10%, respectively (Table 6.1 and Figure. 6.2). Higher COE value of specimens mixed with charcoal 10% could be possibly due to the decomposition of charcoal. This indicated that the higher percentage of charcoal added caused higher porosity in the test fired briquettes. It was likely that the charcoal burning out during firing might leave plenty of pores in the briquettes (Figure. 6.3). Thus, structural changes of crystalline phase, especially quartz conversion could possibly influence the coefficient of thermal expansion of the briquettes.

**Table 6.1** Results of the thermal expansion coefficients and porosity.

Clay briquettes mixed with charcoal (% by weight)	Thermal expansion of test fired briquettes (COE) $\times 10^{-6} \text{ }^{\circ}\text{C}^{-1}$	Apparent porosity (%)
0	8.8	28.96
2.5	6.4	31.45
5.0	8.9	35.14
7.5	9.3	38.93
10	9.8	46.85

**Figure. 6.2** Relation between thermal expansion and porosity (%).



**Figure. 6.3** Cross section of the fired test briquettes with various amounts of charcoal particle size 3 fired at 950 °C (a) Hang Dong test briquettes without charcoal addition, (b) 2.5%, (c) 5.0%, (d) 7.5% and (e) 10%.

### **6.3 Thermal conductivity analysis ( $k$ )**

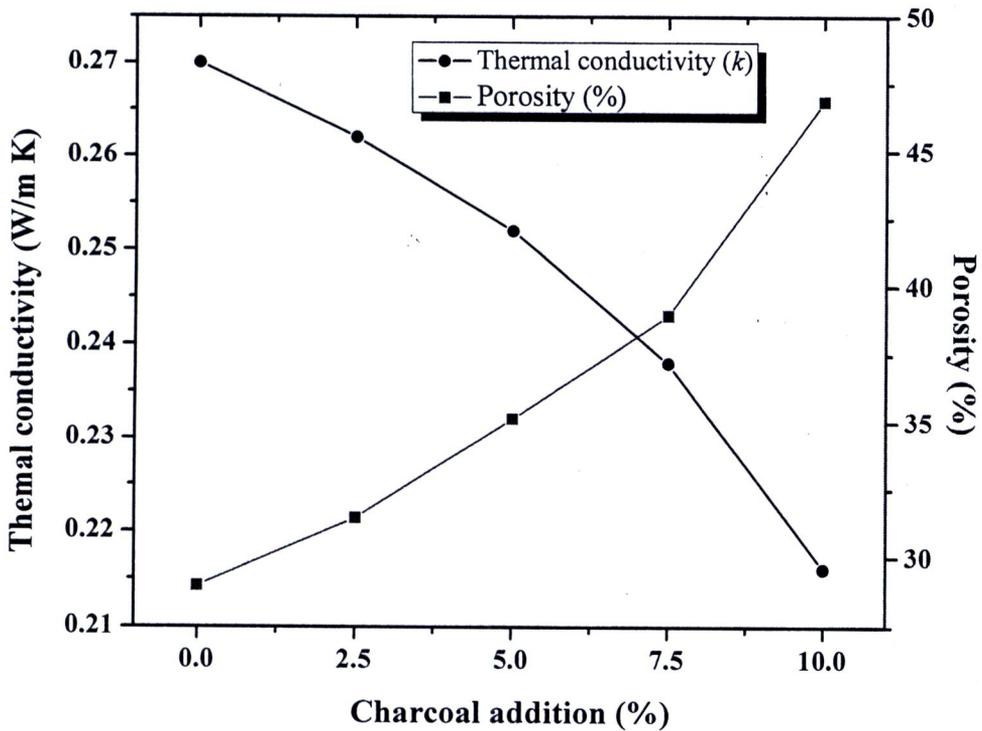
The thermal conductivity analysis was performed on test fired briquettes mixed with charcoal 0%, 2.5%, 5.0%, 7.5% and 10% (size 3) by weight and fired at 950 °C. The thermal conductivity was calculated by using the equation (3.2).

#### **6.3.1 Influence of porosity**

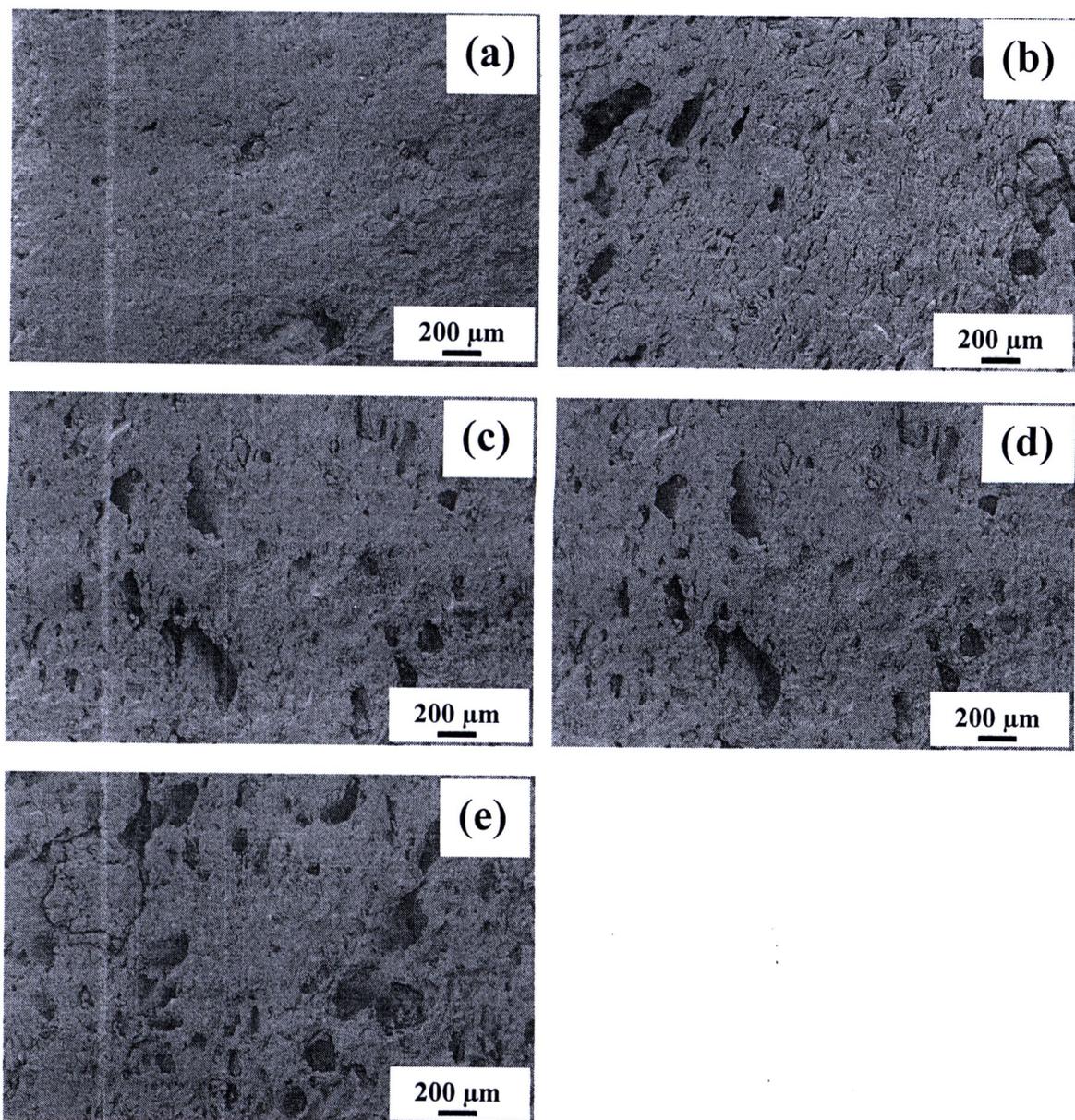
The relation between thermal conductivity and apparent porosity of the briquettes with charcoal addition could be observed in (Table 6.2 and Figure. 6.4). It is evident that increasing the percentage of charcoal caused more porosity. The burning out of charcoal in the body during the firing process caused the porosity in test fired briquettes. The results show that higher percentages of charcoal induce low thermal conductivity to the specimens. This is as a result of the increase of air volume obtained by the burning of the charcoal, a process which leads to pores forming within the samples to make them poor thermal conductors and hence, good backup insulators. From the results, it can be reduced that thermal conductivity decreases with decrease in density and increase in fired briquettes porosity. As a result, the thermal conductivity values vary with porosity as shown in Figures. 6.5 a-e.

**Table 6.2** Results for relation between thermal conductivity and apparent porosity of test fired briquettes.

Clay briquettes mixed with charcoal (% by weight)	Thermal conductivity ( $k$ ) (W/m K)	Apparent porosity (%)
0	0.270	28.96
2.5	0.262	31.45
5.0	0.252	35.14
7.5	0.238	38.93
10	0.216	46.85



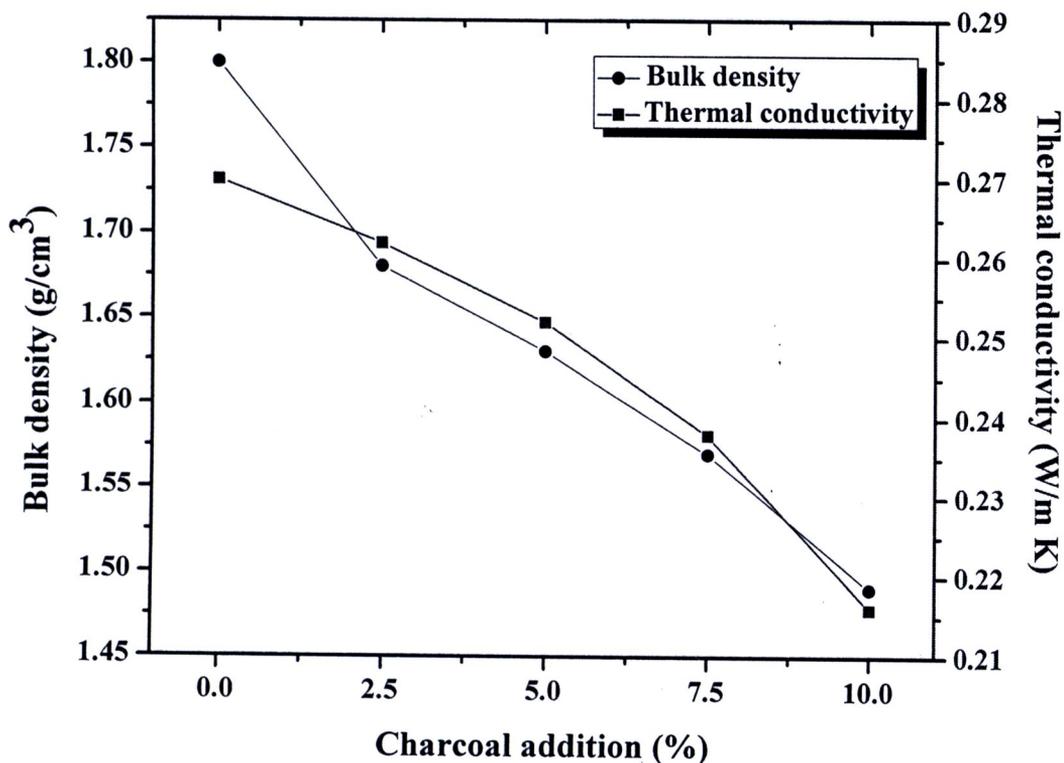
**Figure 6.4** Relation between thermal conductivity ( $k$ ) and porosity (%).



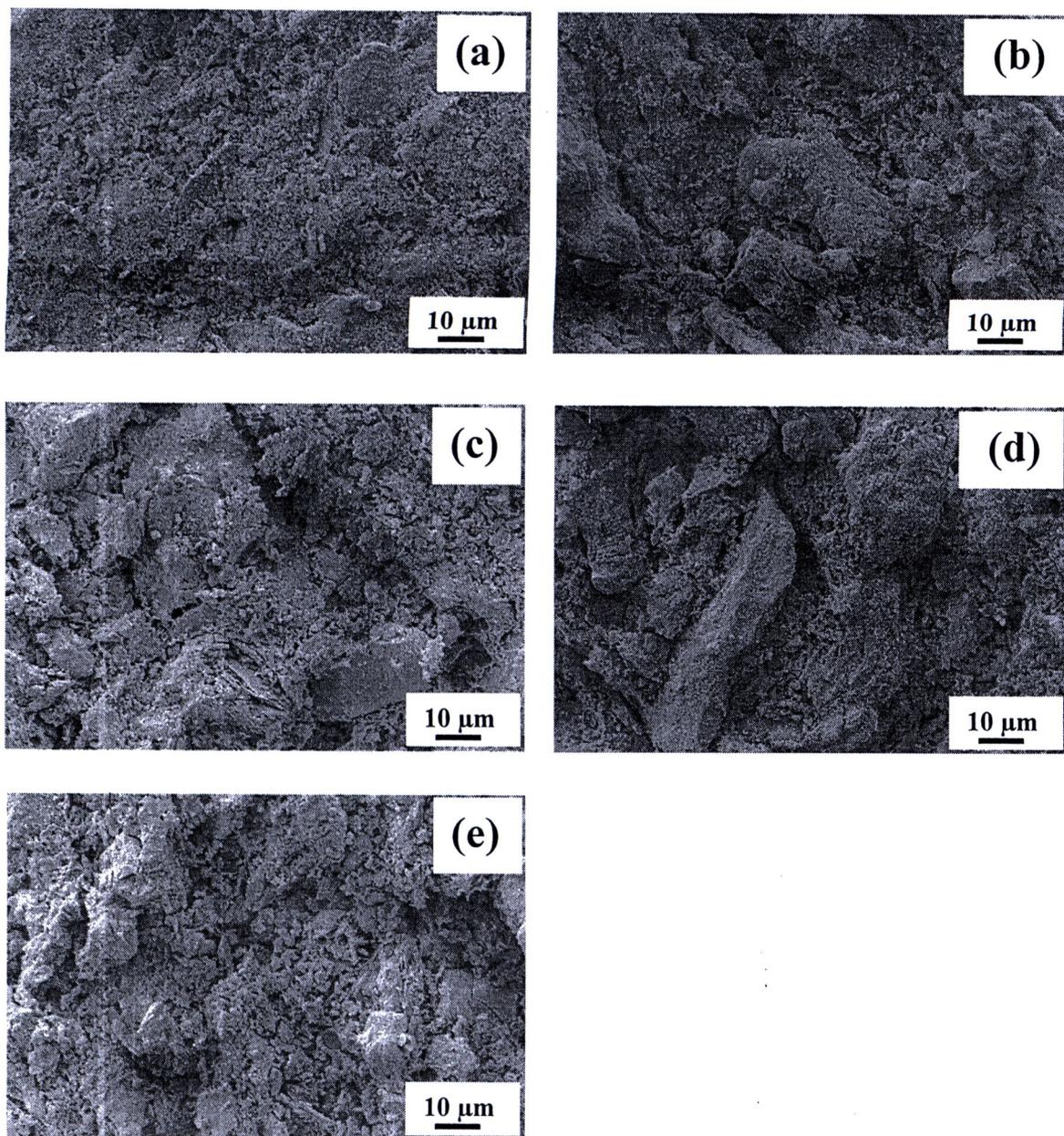
**Figure. 6.5** SEM microphotography of the fired clay briquettes with various amounts of charcoal size 3 fired at 950 °C (a) Hang Dong test briquettes without charcoal addition, (b) 2.5%, (c) 5.0%, (d) 7.5% and (e) 10%.

### 6.3.2 Influence of bulk density

The variation of thermal conductivity as a function of fired bulk density is plotted in Figure. 6.6. The figure shows that, in the range of tested densities, there is relationship between thermal conductivity and bulk density of the samples, such that when the bulk density of the samples decreases, thermal conductivity also decreases. The bulk density of samples was inversely proportional to the quantity of charcoal particles added in the mixture. The bulk density of samples decreased with an increase in the amount of charcoal from 2.5 to 10% (Figure 6.7).



**Figure. 6.6** Evolution of thermal conductivity with bulk density.



**Figure. 6.7** Fractured surface micrographs of the fired clay briquettes with various amounts of charcoal size 3 fired at 950 °C (a) Hang Dong test briquettes without charcoal addition, (b) 2.5%, (c) 5.0%, (d) 7.5% and (e) 10%.

### 6.3.3 Influence of mechanical strength

One of the most effective ways of lowering the thermal conductivity of building materials products is by raising their porosity, for which different lightening additives are typically used that act on green porosity (low-density raw materials) or fired porosity (materials that burn out during firing). One of the disadvantages resulting from this approach is the impairment of the mechanical properties of products that sometimes have structural roles in buildings [49-51]. In this study, analyses the convenience of either decreasing the thermal conductivity of the specimens, by raising porosity. The former case leads to an effect resembling that obtained when charcoal additive are used that burn out during the firing stage.

The mechanical strength-thermal conductivity pairs of values for the specimens are plotted in Figure. 6.8. It shows that thermal conductivity decreases with mechanical strength, because both characteristic on the porous texture of the specimens. The results showed that higher percentages of charcoal induced low thermal conductivity to the samples. From the results, it could be explained that thermal conductivity decreased with a decrease in density and increased with an increase in fired specimen porosity (Figure. 6.3).

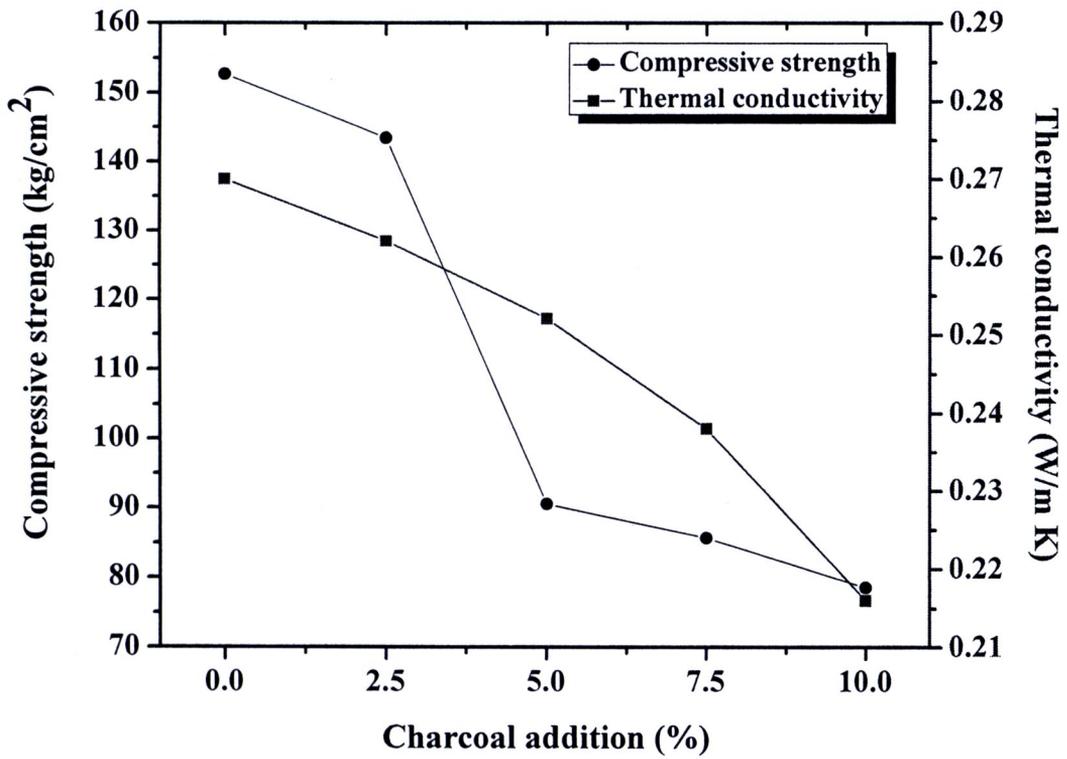


Figure. 6.8 Relation between thermal conductivity and mechanical strength.