# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 CONCLUSIONS

The objective of this study was to investigate the behaviour of hydraulic fracture of sand-bentonite mixtures. The engineering properties of sand-bentonite mixtures were determined, high undrained shear strength and low permeability of sample was shown in test results. The mixtures confirmed that its properties are very well for barrier material, Thai sodium bentonite could be the good choice to mix with selected sand for compacted impervious layer of secure landfill. For 10% of bentonite content the hydraulic conductivity less than requirement of impervious layer. However, detachment characteristics of this ratio should be considered under each condition of location of landfill. And mixing and compacting during construction process must carefully control.

The conclusion of engineering properties test results of sand - bentonite mixture show in Table 5.1. Each ratio gives result of itself, these values can use to be guide for design. And always recognize that different of type of bentonite or sand has influence to the properties of mixture. Engineering properties of supplied bentonite and sand should investigate in laboratory to confirm right values.

The hydraulic fracture test results show that there are at least two mechanisms of lateral hydraulic resistant, resistance of detachment force and resistance of fracture force. For lower than 10% of bentonite content, detachment behaviour of sample show detachment path of all samples. The defined breakthrough pressure of them lower than overburden stress, however, overburden stress has an influence on detachment resistance. In case of 15% of bentonite content and upper the breakthrough pressure is more than overburden stress, detachment resistance of these samples more than fracture resistance.

The breakthrough pressure depends on lateral stress, internal friction angle and cohesion of sample. Cohesion of sample is increase with increase of bentonite content, but internal friction angle is decrease. The normalized breakthrough pressure and overburden stress by cohesion from direct shear test has plotted, the linear trend line give a good reasons. More unique of trends line occur, after divide results in 2 groups, first group is 10 % of bentonite content and lower, another is 15% of bentonite content and upper. This results show that breakthrough pressure for detachment sample different from others. Range of empirical values m and b show in Table 5.2. However, normalized with undrained shear strength from unconfined compression test give more unique of result than normalized with cohesion, the range of empirical value m and b show in Table 5.3. By Camberfort's equation, coefficient of lateral earth pressure at rest has determined the value of it is in possible range. All test results normalized with undrained shear strength has plotted and shown in Figure 5.1.

As mentioned, the sand-bentonite mixture has prepared from laboratory, it's not difficult to control the properties such as; homogeneous, water content, compaction energy. But for construction process this material look difficult to control. Many useful of this material will interest in Thailand, more as develops of industrials and power source. The engineering properties from this study can use to be guide for design, and moreover the behaviour of detachment and hydraulic fracture warn to prevent.

The conclusions of this study based on type of bentonite and type of sand list as following:

1. Thailand Na bentonite mixed with selected sand is an interesting material, which can use to be the impervious material. This mixture give high undrained shear strength and low hydraulic conductivity, in range of 5 – 25% of bentonite content strength is increase with bentonite content.

2. The cohesion of sand-bentonite mixture from direct shear test on 5 – 25% of bentonite content is increase with bentonite content, but the internal friction angle decrease.
3. The hydraulic conductivity of sand bentonite mixture which required for impervious compacted layer of landfill ($1 \times 10^{-7}$ cm/s) can use 10% of bentonite content of mixture. But about this ratio protection from detachment or erosion should recognize.
4. The hydraulic fracture test show that lower than 10% of bentonite content sample can not resist detachment and erosion, the defined breakthrough pressure lower than overburden stress. High pressure operations such as; in situ permeability test or hydraulic jet grouting near this application area should avoid.
5. The breakthrough pressure of more than 15% of bentonite content sample depends on overburden stress, coefficient of lateral earth pressure and cohesion. Breakthrough pressure can determine by empirical formula to control pressure of any operations near this applications area.
6. The empirical formula from this study depend on bentonite content (cohesion or undrained shear strength), and overburden stress.

## 5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

Several other subjects related in this research have been identified that need further investigation. The needs are summarized below:

1. The variable of void or other sand size should investigated, void or pore should effect to detachment and hydraulic fracture of sand bentonite mixture.
2. The critical shear stress of detachment resistance should determine, bentonite particle flow out from hydraulic fracture test should recorded by weight and determine critical hydraulic gradient of initial detachment.
3. The value of empirical formula should define.