CHAPTER 4

TEST RESULTS AND DISCUSSION

4.1 General

The results and discussion on the experiment results are summarized in four aspects as follows;

- Leachability of heavy metals
- Physical properties of spent foundry sand
- Moldability
- Hydraulic Conductivity

4.2 Leachability of heavy metals

The hazardous waste characteristics promulgated by Thai Ministry of Industry designate broad classes of wastes with inherent properties which can be harmful to health or the environment if mismanaged. Test methods and regulatory levels for each characteristics are then established. The leachate extraction procedure outlined in the 6th Notification of the Ministry of Industry (1997) is designed to measure the potential for toxic constituents in the waste to leach out and contaminate ground water. The leachate results of heavy metals from spent foundry sand are shown in Table 4.1-4.2 and comparison with regulatory standard are shown in Table 4.3.

Table 4.1 Leachability of heavy metals from Siam Magotteaux

	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Average (mg/l)	Detection limit (mg/l)
As	0.050	0.050	0.060	0.053	0.050
Ba	0.325	0.344	0.408	0.359	0.001
Cd	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Cr	< 0.007	< 0.007	< 0.007	< 0.007	0.007
Pb	< 0.050	< 0.050	< 0.050	< 0.050	0.050
Hg	< 0.040	< 0.040	< 0.040	< 0.040	0.040
Se	< 0.090	< 0.090	< 0.090	< 0.090	0.090
Ag	< 0.007	< 0.007	< 0.007	< 0.007	0.007

Table 4.2 Leachability of heavy metals from Siam Nawaloha

	Sample 1 (mg/l)	Sample 2 (mg/l)	Sample 3 (mg/l)	Average (mg/l)	Detection limit (mg/l)
As	< 0.050	< 0.050	< 0.050	< 0.050	0.050
Ba	0.266	0.210	0.223	0.229	0.001
Cd	< 0.005	< 0.005	< 0.005	< 0.005	0.005
Cr	< 0.007	< 0.007	< 0.007	< 0.007	0.007
Pb	< 0.050	< 0.050	< 0.050	< 0.050	0.050
Hg	< 0.040	< 0.040	< 0.040	< 0.040	0.040
Se	< 0.090	< 0.090	< 0.090	< 0.090	0.090
Ag	< 0.007	< 0.007	< 0.007	< 0.007	0.007

Table 4.3 Compare the results with regulatory standard

	Siam Magotteaux (mg/l)	Siam Nawaloha (mg/l)	Standard (mg/l)
As	0.053	< 0.050	5
Ba	0.359	0.229	100
Cd	< 0.005	< 0.005	1
Cr	< 0.007	< 0.007	5
Pb	< 0.050	< 0.050	5
Hg	< 0.040	< 0.040	0.2
Se	< 0.090	< 0.090	1
Ag	< 0.007	< 0.007	5

From Table 4.3, it can be seen that the heavy metal content in leachate from spent foundry sand are lower than the standard standards from the 6^{th} Notification of the Ministry of Industry (1997). So, it can be concluded that spent foundry sand are considered as non-hazardous waste.

4.3 Physical properties of spent foundry

Particle size

Particle size distribution was determined in accordance with particle size analysis. Particle size distribution curves are shown in Figure 4.1-4.4.

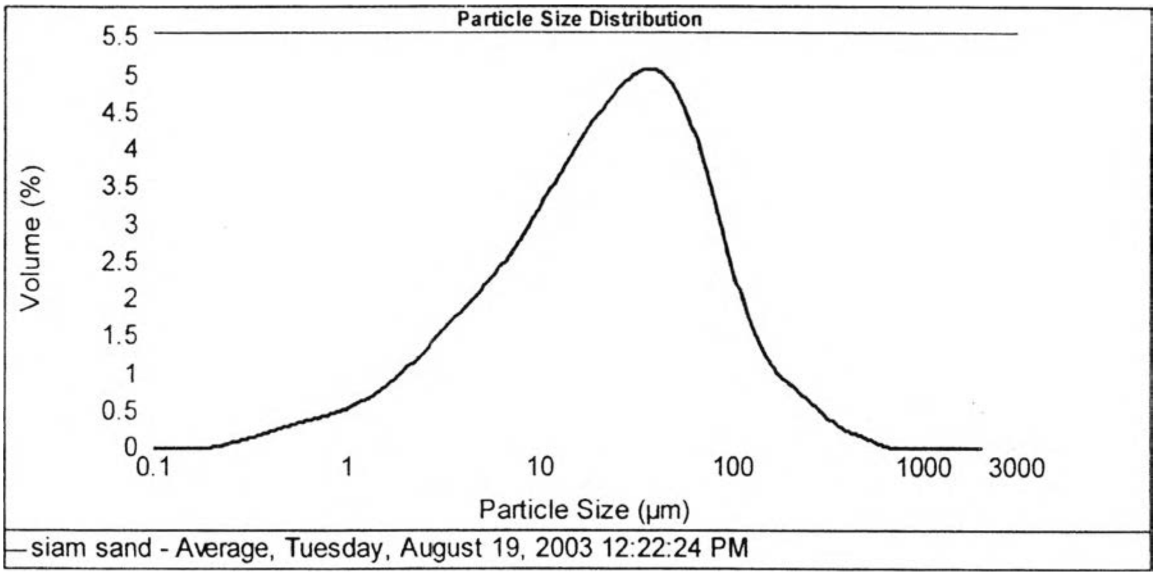

Figure 4.1 Particle size analysis for Siam Magotteaux Foundry Sand

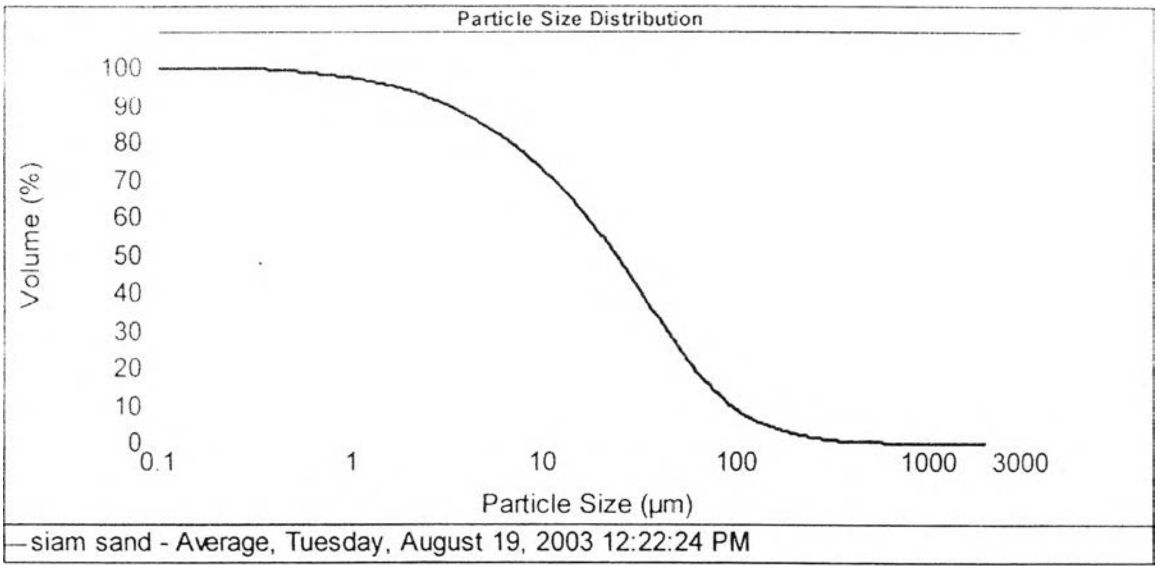

Figure 4.2 Cumulative particle size distribution for Siam Magotteaux Foundry Sand

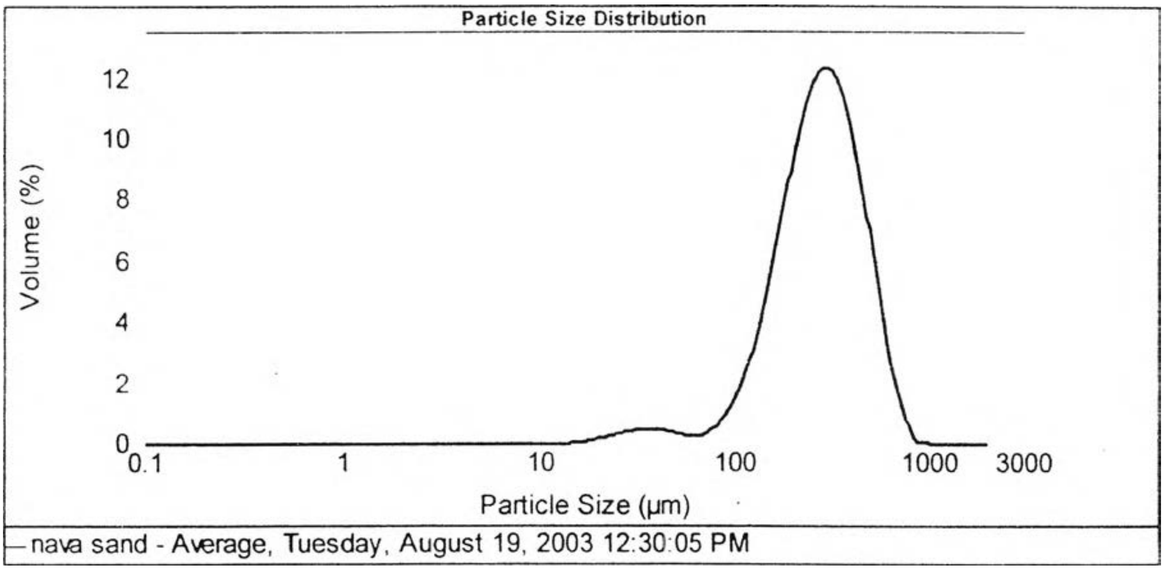

Figure 4.3 Particle size analysis for Siam Nawaloha Foundry Sand

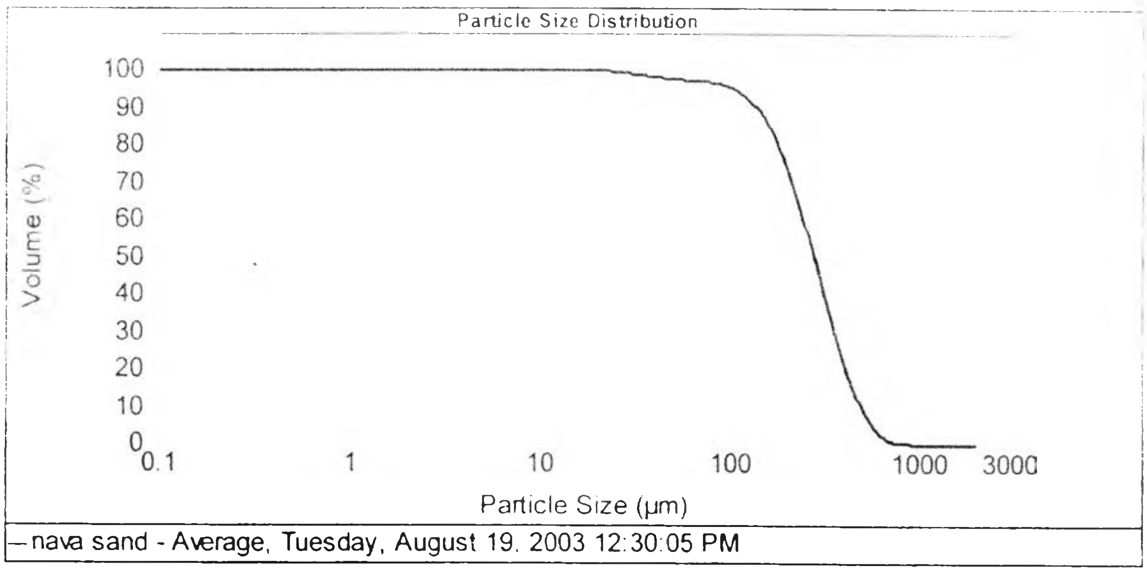

Figure 4.4 Cumulative particle size distribution for Siam Nawaloha Foundry Sand

From the Figure 4.1-4.2, the distribution of sand from Siam Magotteaux is rather wide, all of the particles is larger than 0.3×10^{-3} mm. More than 50 percent of the particles are larger than 2.5×10^{-2} mm and nearly all of the particles are smaller than 3×10^{-1} mm.

From the Figure 4.3-4.4, the distribution of sand from Siam Nawaloha is rather uniform. All of the particles is larger than 3×10^{-2} mm. More than 50 percent of the particles are larger than 3×10^{-1} mm and nearly all of the particles are smaller than 7×10^{-1} mm.

From this experiment, the particle sizes of sand from both factories are not the same. This may cause from the different production processed (ferrous casting, nonferrous casting) or the dust is collected and keep together with spent foundry sand.

Chemical composition

X-ray Fluorescence Spectrometry

Chemical compositions of spent foundry sand are determined by X-ray Fluorescence Spectrometry. Table 4.4 gives a summary of the test results of chemical compositions for foundry sands and the results of chemical compositions for raw mill that used for cement making from previous study (Sisomphon, 2000).

Table 4.4 Chemical compositions of spent foundry sand and raw mill in weight percents

Chemical Composition (% by weight)	Raw mill	Spent foundry sand from Siam Magotteaux	Spent foundry sand from Siam Nawaloha
SiO_2	12.82	67.60	77.15
Al_2O_3	3.78	15.03	6.20
Fe_2O_3	2.24	5.56	1.00
CaO	43.53	2.09	0.72
MgO	0.63	2.22	1.07
SO_3	0.00	0.38	0.27
Na_2O	0.09	3.09	1.03
K_2O	0.41	0.74	0.66
TiO_2	0.16	0.80	0.00
P_2O_5	0.00	0.20	0.00
Loss On Ignition (LOI)	36.14	1.98	11.90

From the previous study, raw mill consisted of 12.82% silicon dioxide (SiO_2), 3.78% aluminium oxide (Al_2O_3), 2.24% iron oxide (Fe_2O_3), 43.53% calcium oxide (CaO), 0.63% magnesium oxide (MgO), 0.09% sodium oxide (Na_2O), 0.41% potassium oxide (K_2O), and 0.16% titanium oxide (TiO_2).

According to the analysis, spent foundry sand from Siam Magotteaux had 67.60% silicon dioxide (SiO_2), 15.03% aluminium oxide (Al_2O_3), 5.56% iron oxide (Fe_2O_3), 2.09% calcium oxide (CaO), 2.22% magnesium oxide (MgO), 0.38% sulfer trioxide (SO_3), 3.09% sodium oxide (Na_2O), 0.74% potassium oxide (K_2O), 0.80% titanium oxide (TiO_2), and 0.20% phosphorous oxide (P_2O_5).

Spent foundry sand from Siam Nawaloha had 77.15% silicon dioxide (SiO_2), 6.20% aluminium oxide (Al_2O_3), 1.00% iron oxide (Fe_2O_3), 0.72% calcium oxide (CaO), 1.07% magnesium oxide (MgO), 0.27% sulfer trioxide (SO_3), 1.03% sodium oxide (Na_2O), and 0.66% potassium oxide (K_2O).

LOI is the result from the organics put as binders as stated in chapter 2. The factories put the binders in different proportion depending on the production processed of each factory.

From this experiment, the major composition of cement raw mill is CaO which is different from the major composition of spent foundry, SiO_2. So it can be inferred that the mechanism of protect liquid pass through of spent foundry sand is different from cement raw mill.

X-ray Diffraction Spectrometry

The result of chemical composition using XRD is consistent with using XRF, the major compositions of spent foundry sand from Siam Magotteaux are SiO_2 and $(Na,Ca,K)_8(Al_6Si_6O_{24})(SO_4)2Cl \cdot H_2O$. While the major compositions of spent foundry sand from Siam Nawaloha are SiO_2, $(Na,Ca,K)_8(Al_6Si_6O_{24})(SO_4)2Cl \cdot H_2O$ and $K_2S_2O_8$. These compositions are from the mixture of sand to improve the conditions to be a effective mold e.g. sodium bentonite, calcium bentonite. The composition of spent foundry sand may comprise of other phases. In this case, the value of other phases is not more than background and it can not specify clearly.

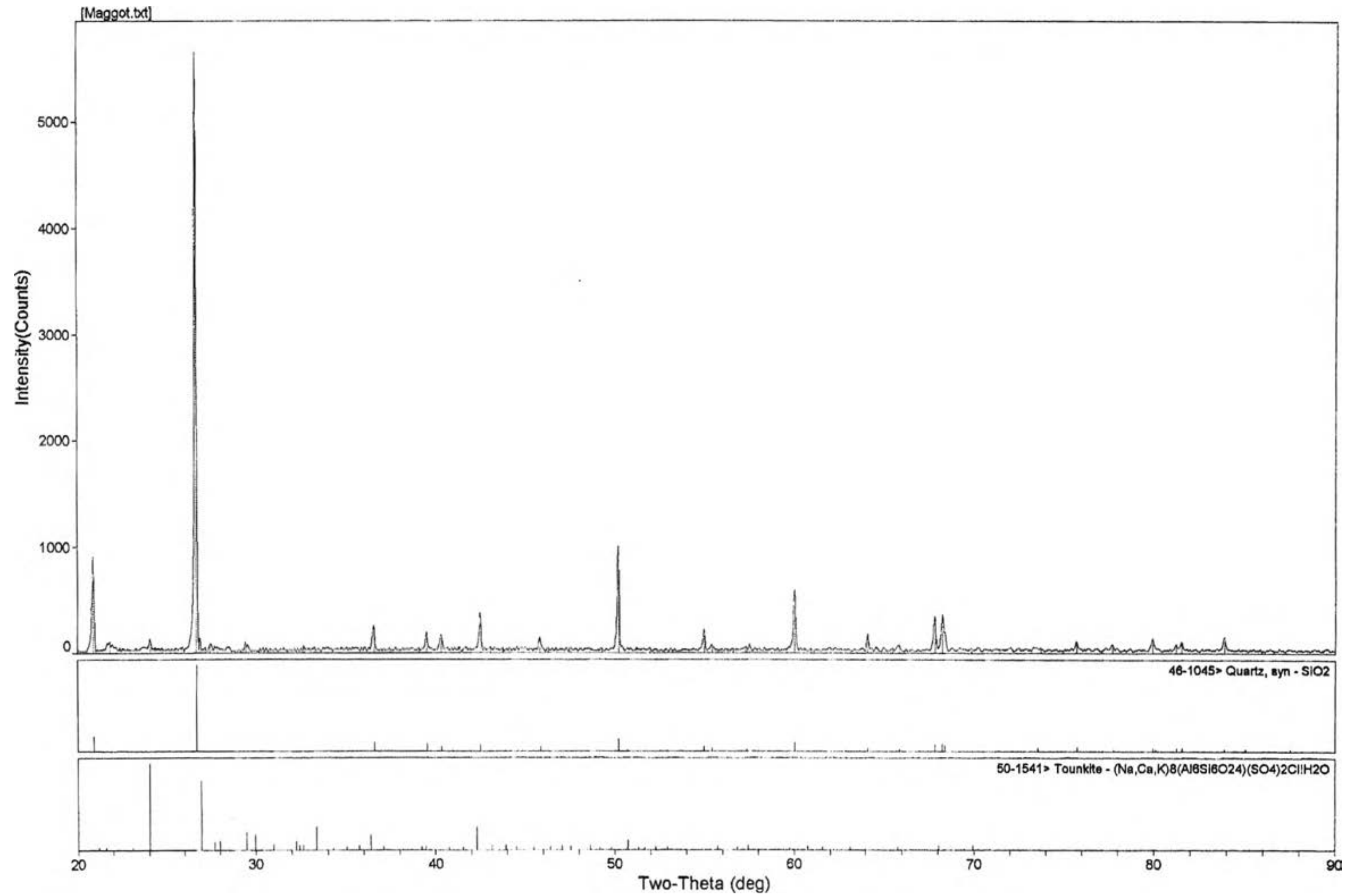

Figure 4.5 X-ray diffraction patterns for Siam Magotteaux spent sand as well as their possible phases, besides SiO_2, $(Na,Ca,K)_8(Al_6Si_6O_{24})(SO_4)2Cl \cdot H_2O$

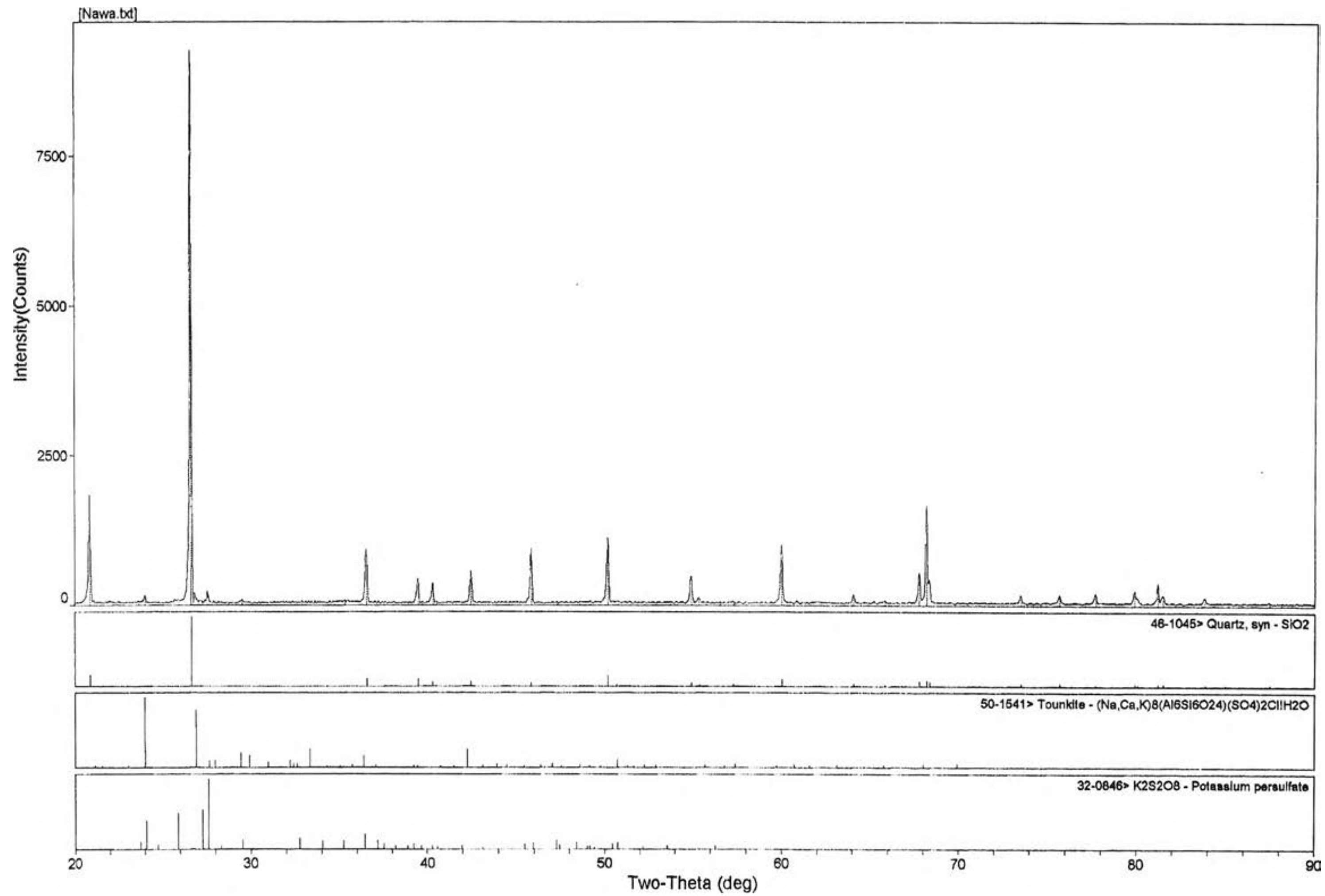

Figure 4.6 X-ray diffraction patterns for Siam Nawaloha spent sand as well as their possible phases, besides SiO_2, $(Na,Ca,K)_8(Al_6Si_6O_{24})(SO_4)2Cl \cdot H_2O$ and $K_2S_2O_8$

4.4 Moldability

Moldability is based on plastic index which is a property in atterberg limit. The samples that have the plastic index mean that they can be molded. Atterberg limits and bentonite content are summarized in Table 4.5.

Table 4.5 Atterberg limits and bentonite content of foundry sands used in study

Sample	Bentonite Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
Siam Magotteaux	27.81	63.50	37.23	26.27
Siam Magotteaux : Siam Nawaloha = 9 : 1	26.17	57.00	32.98	24.02
Siam Magotteaux : Pure sand = 9 : 1	25.03	52.79	27.33	25.46
Siam Magotteaux : Siam Nawaloha = 8 : 2	24.53	53.27	26.51	26.76
Siam Magotteaux : Siam Nawaloha = 7 : 3	22.88	49.06	27.02	22.04
Siam Magotteaux : Pure sand = 8 : 2	22.25	47.08	25.70	21.38
Siam Magotteaux : Siam Nawaloha = 6 : 4	21.24	44.73	25.39	19.34
Siam Magotteaux : Siam Nawaloha = 5 : 5	19.60	42.51	23.52	18.99
Siam Magotteaux : Pure sand = 7 : 3	19.47	42.12	24.06	18.06
Siam Magotteaux : Pure sand = 6 : 4	16.69	37.91	21.13	16.78
Siam Magotteaux : Pure sand = 5 : 5	13.91	-*	-*	-*
Siam Nawaloha	11.39	-*	-*	-*

Remark : * = unmoldable

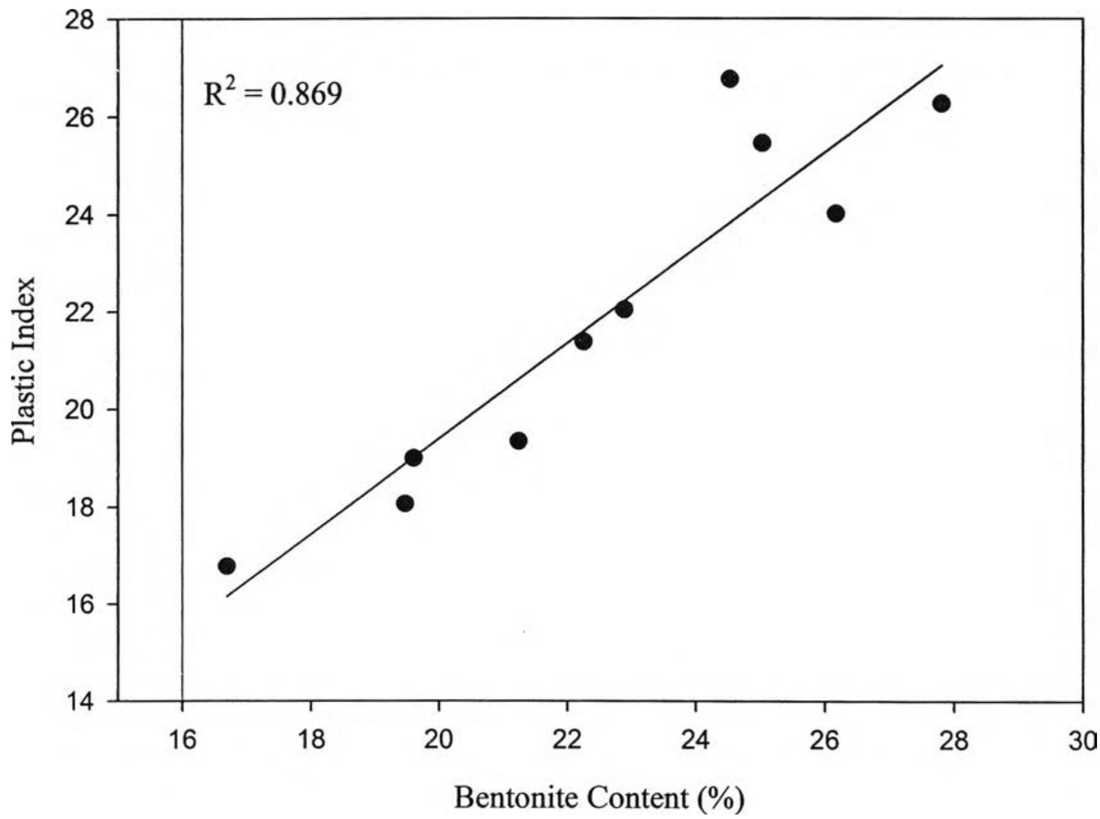

Figure 4.7 Plastic Index versus Bentonite Content

As shown in Figure 4.7, plasticity of foundry sands increases as the bentonite content increases. The relationship is quite linear. From Table 4.5, the samples that have bentonite content 11.39% and 13.91% can not find the plastic index which mean they can not be molded. Foundry sands are molded only when the bentonite content is greater than 16%.

4.5 Hydraulic Conductivity

Siam Magotteaux sand is used as base sand because samples from Siam Magotteaux have a lot of bentonite content. The sand is mixed with Siam Nawaloha sand and pure sand to make wide range of bentonite content. Bentonite content, density and hydraulic conductivity (K) are summarized in Table 4.6.

Table 4.6 Bentonite content, density and hydraulic conductivity of foundry sands

Sample	Bentonite Content (%)	Density (g/cm^3)	K (cm/sec)
Siam Magotteaux 1	27.81	1.68	1.24×10^{-8}
Siam Magotteaux 2	27.81	1.74	3.96×10^{-9}
Siam Nawaloha 1	11.39	1.94	4.93×10^{-9}
Siam Nawaloha 2	11.39	2.04	5.92×10^{-9}
Siam Magotteaux : Siam Nawaloha = 8:2	24.53	1.76	9.10×10^{-9}
Siam Magotteaux : Siam Nawaloha = 7:3	22.88	1.68	1.20×10^{-8}
Siam Magotteaux : Siam Nawaloha = 6:4	21.24	1.78	1.27×10^{-8}
Siam Magotteaux : Pure sand = 8:2	22.25	1.80	9.12×10^{-9}

From the table, the data from the first experiment of both factories (Siam Magotteaux 1 and Siam Nawaloha 1) which is not use for finding the relation since the result from the first experiment may be error due to lack of experienced.

Hydraulic conductivity at density ranges of 1.68-2.04 g/cm^3 versus bentonite content is shown in Figure 4.8.

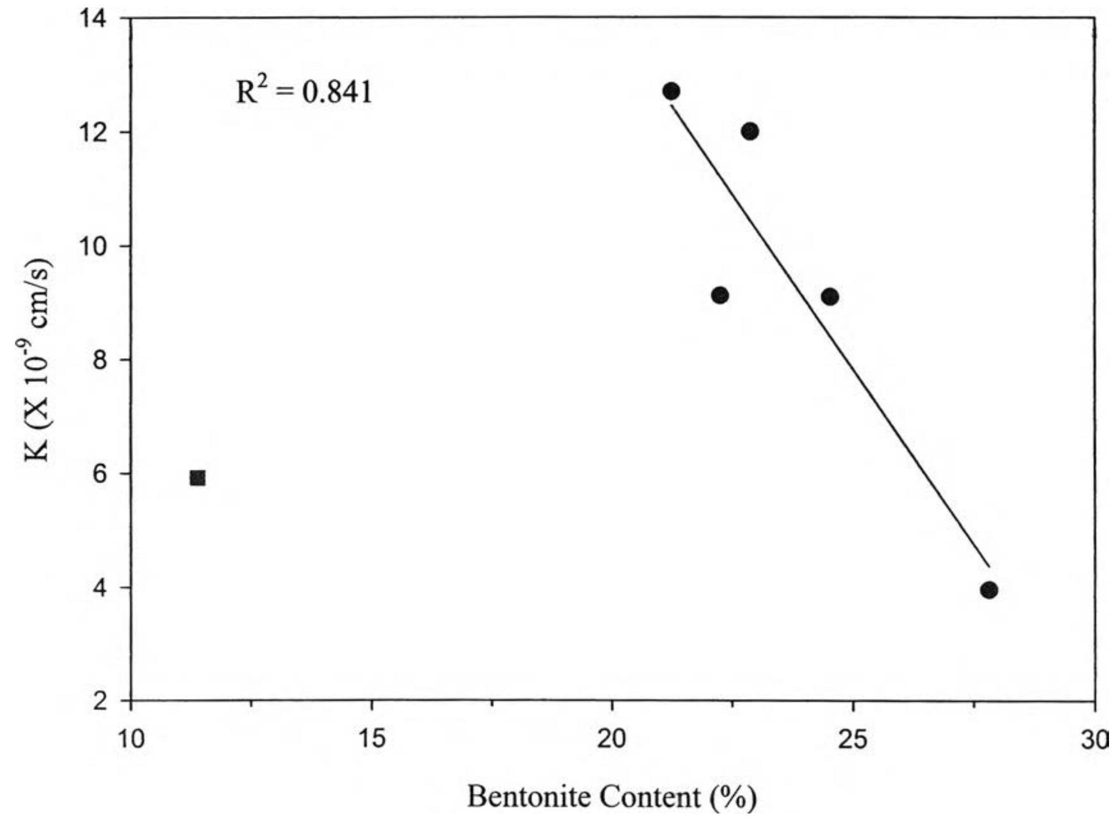

Figure 4.8 Relationship between K and bentonite content

The relationship between hydraulic conductivity and bentonite content for each foundry sand was initially determined using standard proctor effort. From Figure 4.8, it can be seen that in the density ranges of 1.68-2.04 g/cm^3, the hydraulic conductivity decreases as the bentonite content increases and the hydraulic conductivity is less than 1×10^{-7} cm/s for the bentonite content range of 11-28%. The relationship between hydraulic conductivity and bentonite is linear and can be represented by $y = -1.229x + 38.557$ where y = hydraulic conductivity and x = bentonite content. However, the equation can be used in this study only because other properties of mixture that might affect permeabilities such as grain size distribution, mineral content, etc., can vary from place to place.

Hydraulic conductivity at bentonite content ranges of 11.4-27.8% versus density is shown in Figure 4.9.

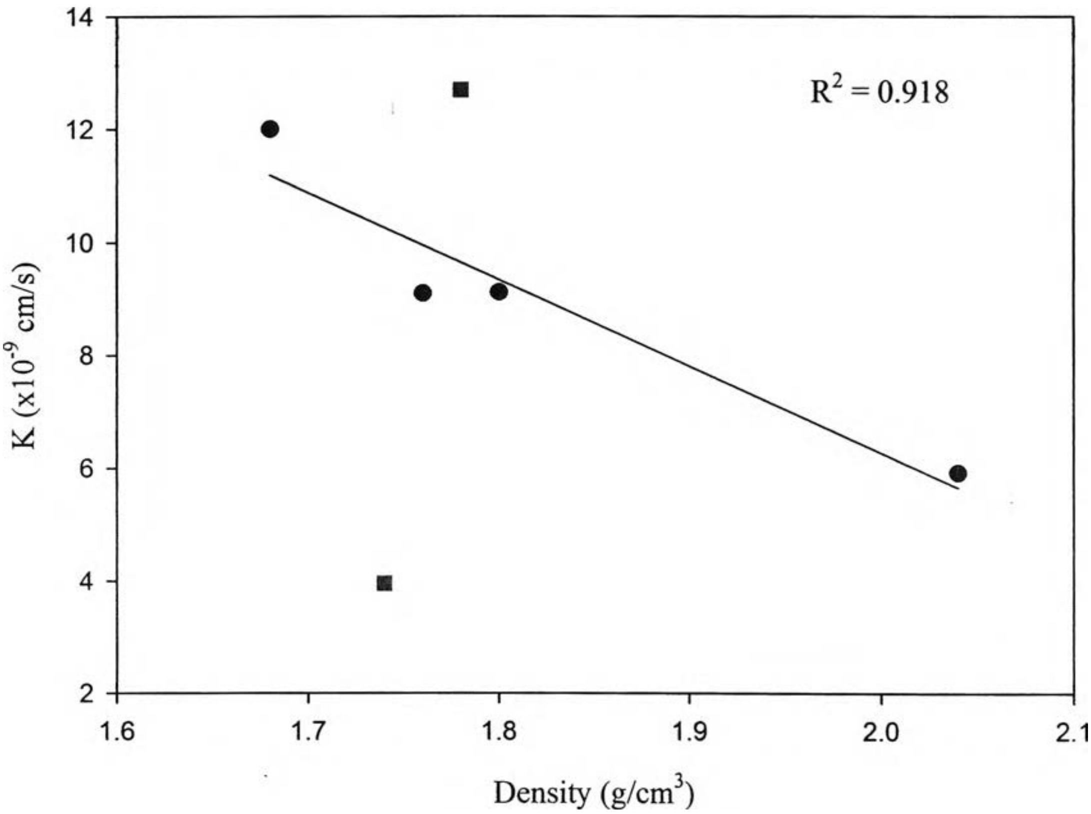

Figure 4.9 Relationship between K and density

As can be seen in Figure 4.9, in the bentonite content ranges of 11.4-27.8% the hydraulic conductivity decreases as the density increases because when the density increases, the void ratio decreases.

It is now recognized that hydraulic conductivity less than 10^{-7} cm/s can be obtained for spent foundry sand that has bentonite content greater than 11%. However, the bentonite content should be greater than 16% to make it moldable. The following can be concluded that, the bentonite content greater than 16% to make it moldable and obtain hydraulic conductivity less than 10^{-7} cm/s.