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APPENDICES

APPENDIX A

TEST FOR BENTONITE IN MOLDING SAND

Test for Bentonite in Molding Sand

Methylene Blue Procedure

Pyrophosphate Method – Tentative Standard

The methylene blue test measures the amount of active clay present by determining the base exchange capacity of the bentonite. The number of exchangeable ions present is determined by replacing these ions with methylene blue dye, which is standardized in terms of milliliters of dry for each percent of bentonite. The methylene blue requirement will vary depending on the purity and nature of the bentonite as well as on the mechanical treatment prior to the titration. The methylene blue requirement does not include the deed-burned clay and inert fines that can be present.

Definition, Total Bentonite

The present bentonite as determined by the methylene blue procedure on a thoroughly dispersed sand mixture after treatment with an ultrasonic scrubber. If other mechanical means are used for dispersing the bentonite sample, lower values will be obtained.

Equipment

The test apparatus shall consist of a 250 ml tall form of stainless steel beaker with a rubber ring attached, a 50 ml burette, a mechanical stirrer with an ASTM agitator disc mounted on a 1550 rpm motor and an ultrasonic unit developing a 50-55 kHz signal. Filter paper Whatman No. 50 or equivalent

Test Procedure

A 5.0 gm sample of dried molding sand is weighted and transferred to a 250 ml beaker. Fifty milliliters of the 2 percent tetrasodium pyrophosphate ($Na_4P_2O_7$) solution are made to the sample in the beaker. The ultrasonic unit is turned on and the sample subjected to the ultrasonic scrubbing action for 5 min.

The beaker is then placed under the methylene blue burette and 80 to 90 percent of the estimated methylene blue required is added. The suspension is then stirred 2 min. with a stirrer motor rated at 1550 rpm. Using a glass rod, a single drop of the suspension is place on a sheet of hardened filter paper (No. 50 Whatman or equivalent) to test for the presence of a blue-green halo. The sample is titrated with methylene blue in 1 ml increments followed each time by 2 min. of stirring until a blue-green halo appears surrounding the dark spot on the filter paper.

The end-point is then checked by giving the suspension another 2 min. of stirring and transferring a drop to the filter paper to be sure that the halo persists. The volume of methylene blue required is recorded for calculation of the percent total bentonite.

Test Procedure for Bentonite Content of Premix Sand Additives

A 0.50 gm sample of as-received premix, 4.50 gm of new sand and 5.00 gm of 220 mesh silicon carbide are placed in a 250 ml beaker. Fifty milliliters of the 2 percent tetrasodium pyrophosphate solution are added and the mixture scrubbed in the ultrasonic accessory for 7 min. Titrate as described above to end point.

Tolerance

The methylene blue requirement of samples tested by different operators should not vary more than 1 ml. The samples should be weighed on a balance having a sensitivity of ±0.01 gm.

Standardization and Calibration

To determine the equivalency of the methylene blue solution, weigh the equivalent clay (as received) and new sand on the basis of a 5.00 gm sample. To provide additional abrading surfaces, 5 gm of 220 mesh silicon carbide are added to the mixture in the beaker. The silicon carbide helps the ultrasonic accessory break up the clay colonies and completely disperse the clay. Example, to produce a 6 percent bentonite equivalent mix, weigh out 0.30 gm of clay (as-received) and 4.7 gm of new sand. Add 5 gm of 220 mesh silicon carbide, 50 ml of $Na_4P_2O_7$ solution and scrub in the ultrasonic accessory for 7 min to ensure complete dispersion. If an ultrasonic unit is not available, an alternative procedure is to boil the solution for 10 min and titrate when cool. Titrate as described above using 2 min stirring periods after the addition of each ml of methylene blue. Divide the methylene blue requirement in milliliters by 6 to calculate the calibration factor or quotient for the bentonite.

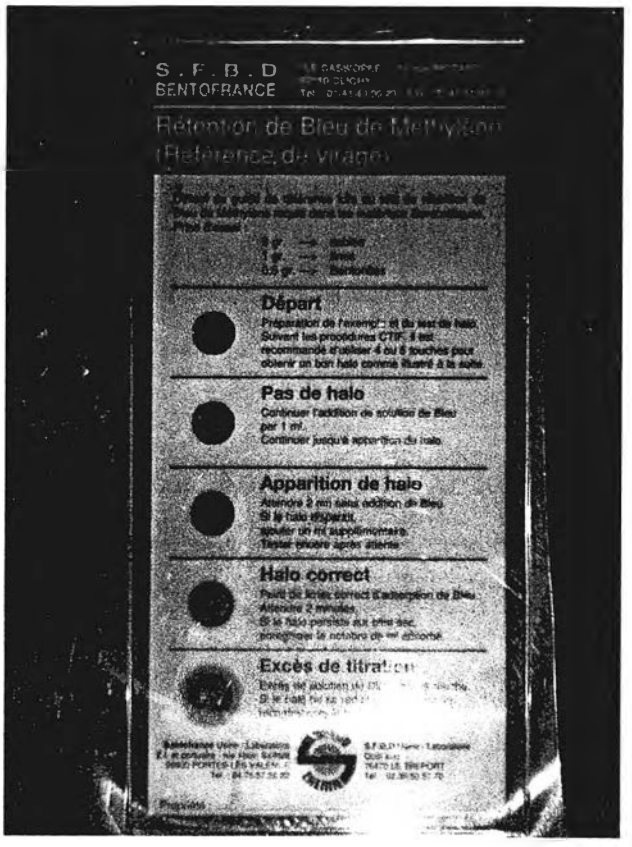


Figure A.1 Blue halo

APPENDIX B
BENTONITE CONTENT

Bentonite Content

Pure bentonite

Sample	Bentonite (g)	Bentonite + Pure sand (g)	% Bentonite	MB (ml)
1	0.1061	1.0053	10.55	13
2	0.1038	1.0126	10.25	12
3	0.1035	1.0033	10.32	13

Bentonite 10.37% use MB 12.67 ml

Spent sand

Industry	Sample	Sand (g)	MB (ml)	% Bentonite
Siam Magotteaux	1	0.9972	33	26.86
	2	1.0012	33	26.86
	3	1.0018	34	27.67
	4	1.0031	34	27.67
	5	0.9991	36	29.3
	6	1.0178	35	28.49
			average	27.81
Siam Nawaloha	1	1.0445	14	11.39
	2	1.0001	14	11.39
	3	1.0009	14	11.39
	4	1.0062	14	11.39
			average	11.39

* Determined by Methylene Blue Procedure

APPENDIX C
HYDRAULIC CONDUCTIVITY

Hydraulic Conductivity

Siam Magotteaux sample 1

Sample diameter 10.12 cm

Sample height 11.57 cm

Sample area 80.47 cm^2

Weight of mold + soil 3573 g

Weight of mold 2011 g

Weight of soil 1562 g

Density of soil 1.68 g/cm^3

Constant head permeability test : testing head = 2000 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	14.17	27
2	86400	16.48	27
3	86400	15.05	27
4	86400	14.65	27
5	86400	13.94	27

$$K = \frac{QL}{ATh}$$

$$= \frac{14.86 * 11.57}{80.47 * 86400 * 2000}$$

$$= 1.24 * 10^{-8} \text{ cm/sec}$$

Siam Magotteaux sample 2

Sample diameter 10.12 cm

Sample height 11.57 cm

Sample area 80.47 cm^2

Weight of mold + soil 3633 g

Weight of mold 2013 g

Weight of soil 1620 g

Density of soil 1.74 g/cm^3

Constant head permeability test : testing head = 2200 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	5.10	27
2	86400	5.75	27
3	86400	6.12	27
4	86400	4.55	27
5	86400	4.68	27

$$K = \frac{QL}{ATh}$$

$$= \frac{5.24 * 11.57}{80.47 * 86400 * 2200}$$

$$= 3.96 * 10^{-9} \text{cm/sec}$$

Siam Nawaloha sample 1

Sample diameter 10.12 cm

Sample height 11.66 cm

Sample area 80.47 cm^2

Weight of mold + soil 3872 g

Weight of mold 2055 g

Weight of soil 1817 g

Density of soil 1.94 g/cm^3

Constant head permeability test : testing head = 2000 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	4.67	27
2	86400	6.97	27
3	86400	6.72	27
4	86400	5.69	27
5	86400	5.36	27

$$K = \frac{QL}{ATh}$$

$$= \frac{5.88 * 11.66}{80.47 * 86400 * 2000}$$

$$= 4.93 * 10^{-9} \text{ cm/sec}$$

Siam Nawaloha sample 2

Sample diameter 10.12 cm

Sample height 11.66 cm

Sample area 80.47 cm^2

Weight of mold + soil 3979 g

Weight of mold 2065 g

Weight of soil 1914 g

Density of soil 2.04 g/cm^3

Constant head permeability test : testing head = 2200 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	7.08	27
2	86400	7.55	27
3	86400	8.10	27
4	86400	8.25	27
5	86400	7.82	27

$$K = \frac{QL}{ATh}$$

$$= \frac{7.76 * 11.66}{80.47 * 86400 * 2200}$$

$$= 5.92 * 10^{-9} cm/sec$$

Siam Magotteaux : Siam Nawaloha = 8:2

Sample diameter 10.12 cm

Sample height 11.60 cm

Sample area 80.40 cm^2

Weight of mold + soil 3656.5 g

Weight of mold 2010.5 g

Weight of soil 1646 g

Density of soil 1.76 g/cm^3

Constant head permeability test : testing head = 2100 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	14.74	25
2	86400	12.98	25
3	86400	11.06	25
4	86400	9.99	25
5	86400	11.08	25
6	86400	8.86	25

$$K = \frac{QL}{ATh}$$

$$= \frac{11.45 * 11.60}{80.40 * 86400 * 2100}$$

$$= 9.1 * 10^{-9} \text{ cm/sec}$$

Siam Magotteaux : Siam Nawaloha = 7:3

Sample diameter 10.12 cm

Sample height 11.57 cm

Sample area 80.47 cm^2

Weight of mold + soil 3573 g

Weight of mold 2011 g

Weight of soil 1562 g

Density of soil 1.68 g/cm^3

Constant head permeability test : testing head = 2100 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	15.79	25
2	86400	15.96	25
3	86400	15.15	25
4	86400	14.79	25
5	86400	14.05	25
6	86400	15.20	25

$$K = \frac{QL}{ATh}$$

$$= \frac{15.16 * 11.57}{80.47 * 86400 * 2100}$$

$$= 1.20 * 10^{-8} \text{ cm/sec}$$

Siam Magotteaux : Siam Nawaloha = 6:4

Sample diameter 10.12 cm

Sample height 11.66 cm

Sample area 80.47 cm^2

Weight of mold + soil 3727.50 g

Weight of mold 2055 g

Weight of soil 1672.50 g

Density of soil 1.78 g/cm^3

Constant head permeability test : testing head = 2100 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	16.73	25
2	86400	16.38	25
3	86400	15.74	25
4	86400	15.65	25
5	86400	15.04	25

$$K = \frac{QL}{ATh}$$

$$= \frac{15.91 * 11.66}{80.47 * 86400 * 2100}$$

$$= 1.27 * 10^{-8} \text{ cm/sec}$$

Siam Magotteaux : Pure sand = 8:2

Sample diameter 10.12 cm

Sample height 11.60 cm

Sample area 80.40 cm^2

Weight of mold + soil 3730.50 g

Weight of mold 2054 g

Weight of soil 1676.50 g

Density of soil 1.80 g/cm^3

Constant head permeability test : testing head = 2100 cm

Trial No.	Time (s)	Q (cc)	T (°C)
1	86400	12.58	25
2	86400	11.82	25
3	86400	10.21	25
4	86400	10.68	25
5	86400	9.86	25
6	86400	13.67	25

$$K = \frac{QL}{ATh}$$

$$= \frac{11.47 * 11.60}{80.40 * 86400 * 2100}$$

$$= 9.12 * 10^{-9} \text{ cm/sec}$$

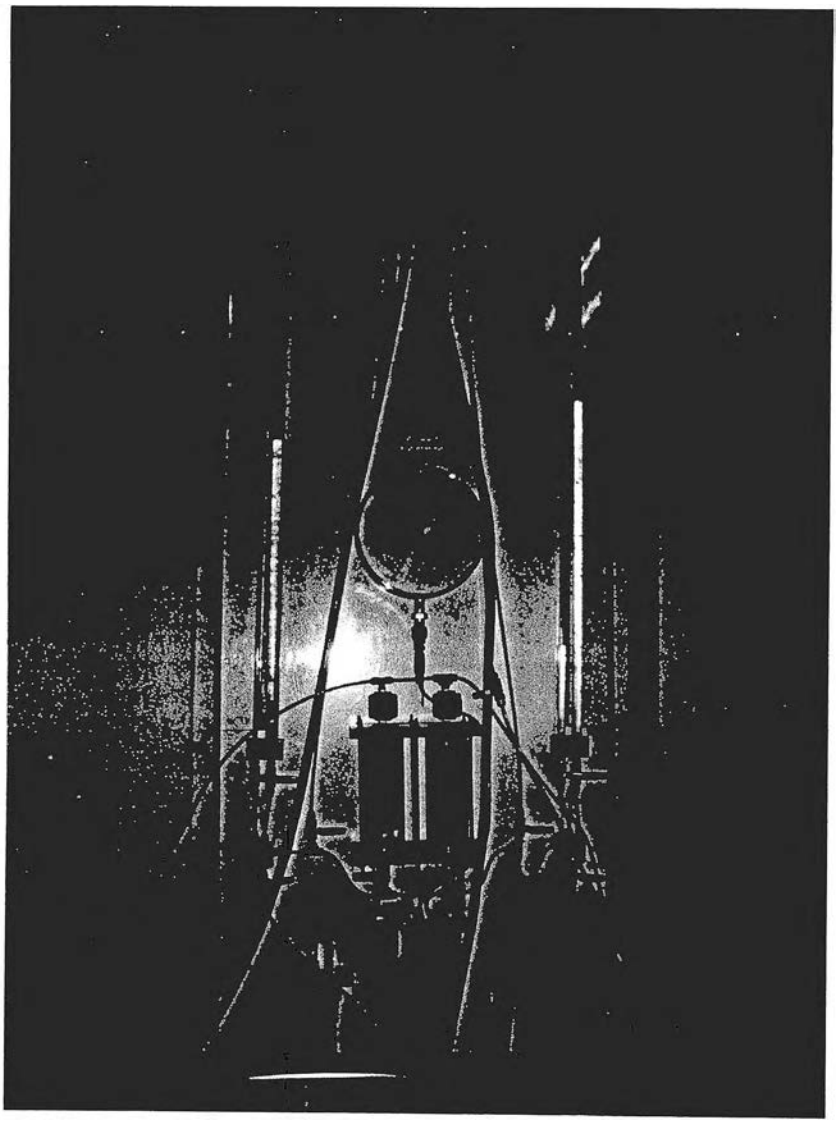


Figure C.1 Permeameter

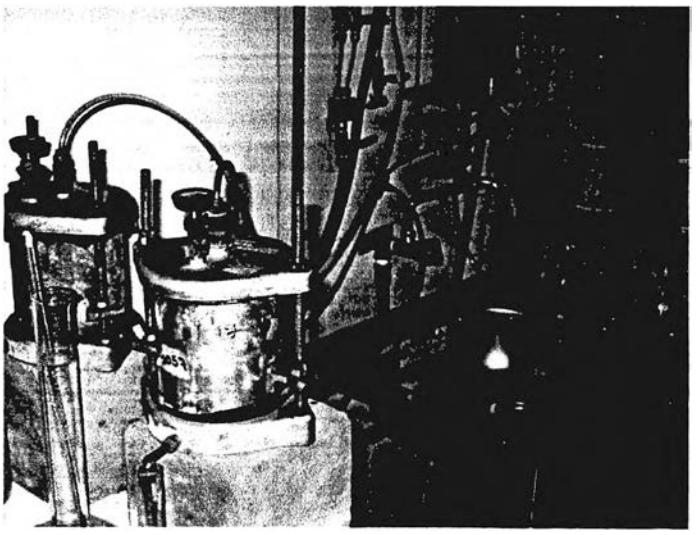


Figure C.2 Mold

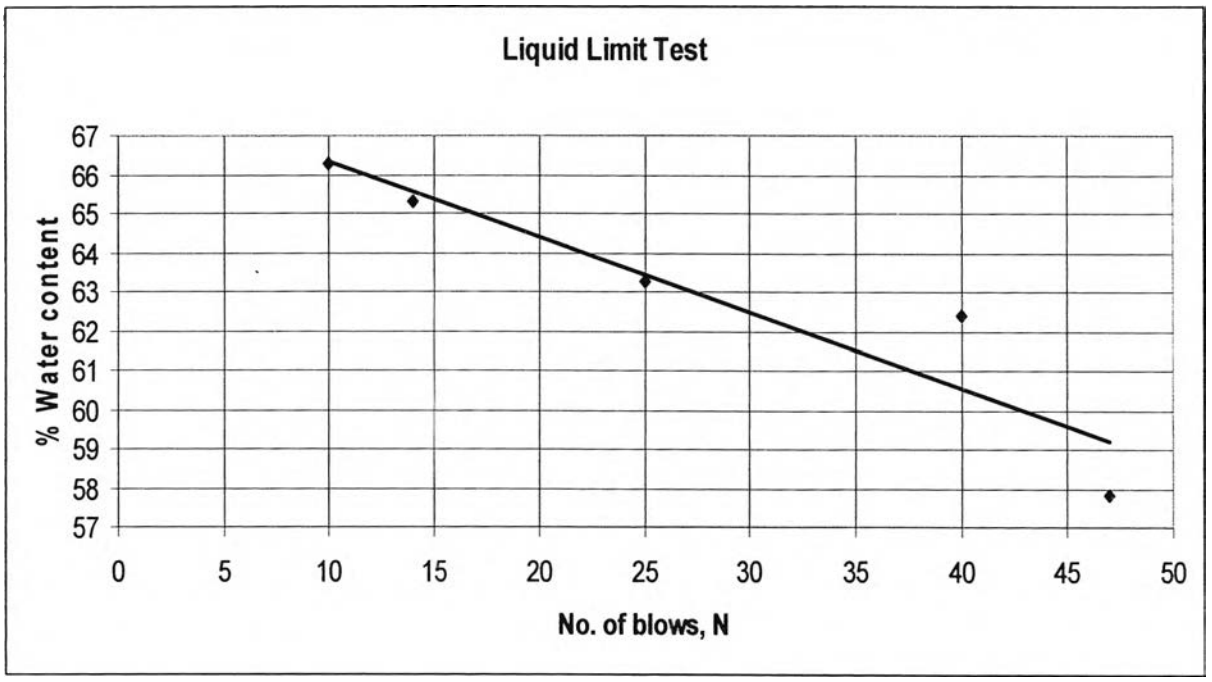
Figure C.3 Soil sample after permeability test

APPENDIX D
LIQUID AND PLASTIC LIMITS

Liquid and Plastic limits

Siam Magotteaux (Bentonite Content = 27.81%)

No. of blows, N	47	40	25	14	10
Can no.	1	2	3	4	5
Wet soil + can, gm.	34.49	28.16	26.75	26.36	24.53
Dry soil + can, gm.	29.32	23.05	22.43	21.80	20.68
Weight of can, gm.	20.58	14.86	15.60	14.82	14.87
Weight of water, gm.	5.17	5.11	4.32	4.56	3.85
Weight of dry soil, gm.	8.94	8.19	6.83	6.98	5.81
% Water content	57.83	62.39	63.25	65.33	66.27



Liquid limit = 63.5

Can no.	1	2
Wet soil + can, gm.	39.23	36.86
Dry soil + can, gm.	35.46	34.10
Weight of can, gm.	25.66	26.43
Weight of water, gm.	3.77	2.76
Weight of dry soil, gm.	9.8	7.67
% Water content	38.47	35.98

$$\text{Plastic limit} = \frac{38.47 + 35.98}{2}$$

$$= 37.23$$

$$\text{Plastic Index} = 63.5 - 37.23$$

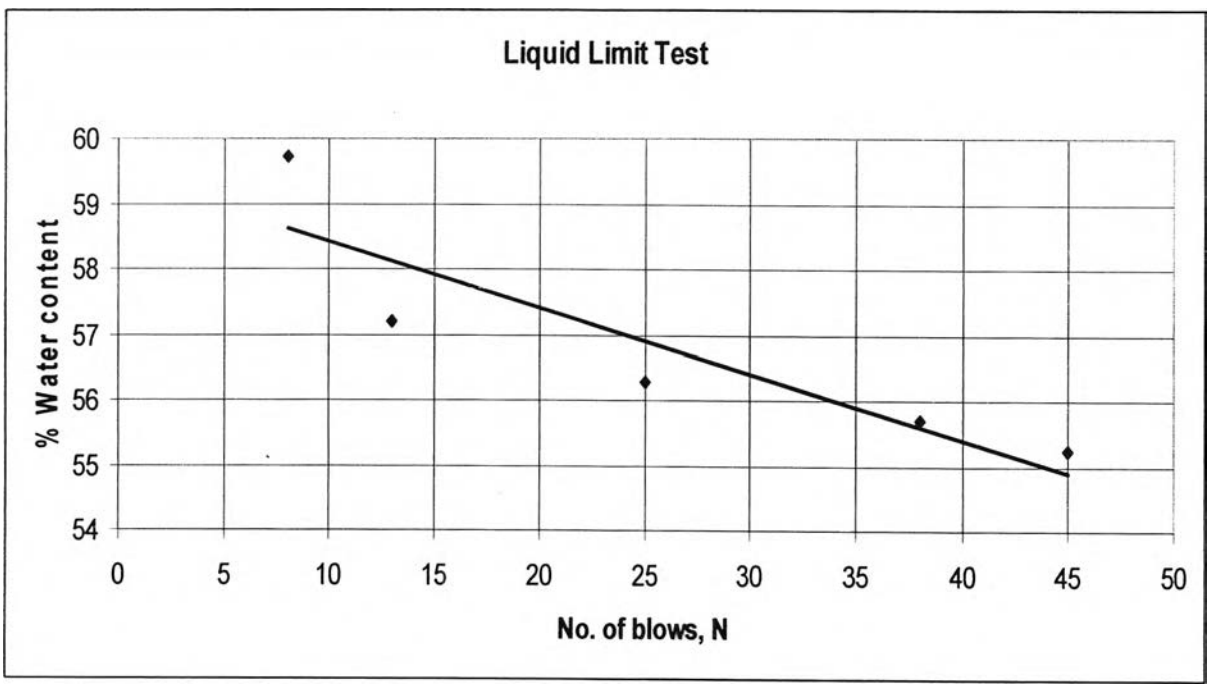
$$= 26.27$$

Siam Nawaloha (Bentonite Content = 11.39%)

Spent foundry sand from Siam Nawaloha is considered as non-plastic, so it can't find LL. and PL.

Siam Magotteaux : Siam Nawaloha = 9 : 1 (Bentonite = 26.17%)

No. of blows, N	45	38	25	13	8
Can no.	1	2	3	4	5
Wet soil + can, gm.	32.80	31.57	33.75	28.76	33.50
Dry soil + can, gm.	28.21	27.55	28.64	25.02	29.29
Weight of can, gm.	19.90	20.33	19.56	18.48	22.24
Weight of water, gm.	4.59	4.02	5.11	3.74	4.21
Weight of dry soil, gm.	8.31	7.22	9.08	6.54	7.05
% Water content	55.23	55.68	56.28	57.19	59.72



Liquid limit = 57

Can no.	1	2
Wet soil + can, gm.	31.43	31.29
Dry soil + can, gm.	28.50	28.68
Weight of can, gm.	19.75	20.64
Weight of water, gm.	2.93	2.61
Weight of dry soil, gm.	8.75	8.04
% Water content	33.49	32.46

$$\text{Plastic limit} = \frac{33.49 + 32.46}{2}$$

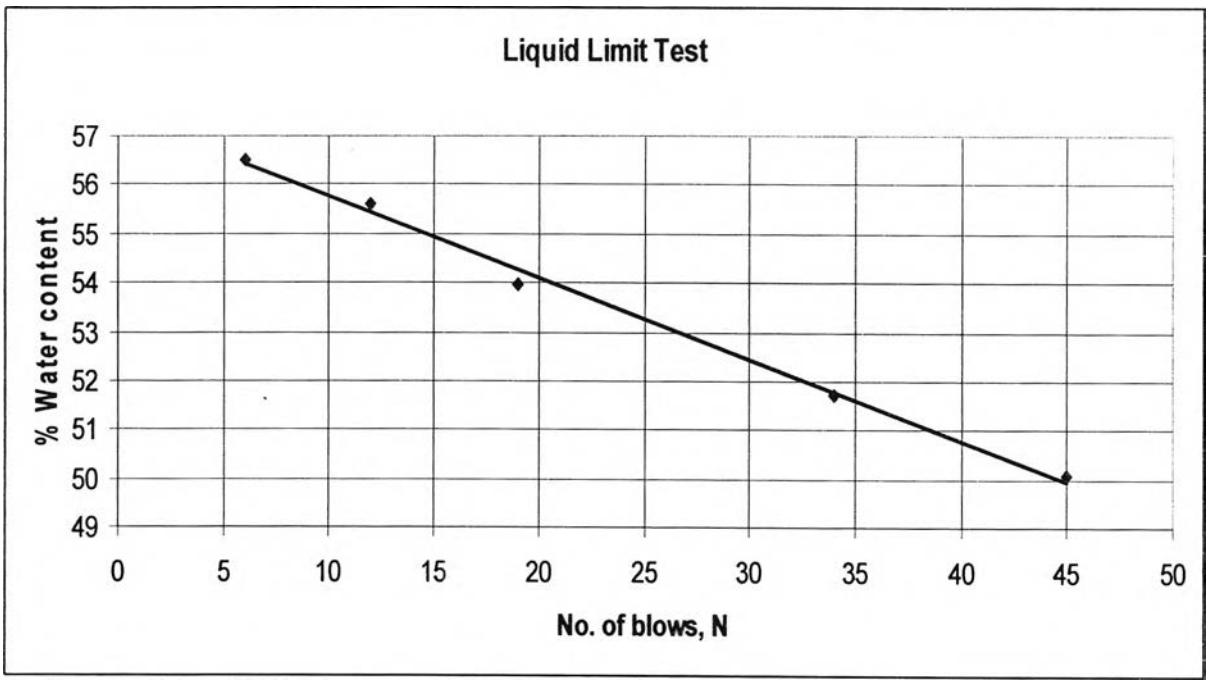
$$= 32.98$$

$$\text{Plastic Index} = 57 - 32.98$$

$$= 24.02$$

Siam Magotteaux : Siam Nawaloha = 8 : 2 (Bentonite = 24.53%)

No. of blows, N	45	34	19	12	6
Can no.	1	2	3	4	5
Wet soil + can, gm.	29.80	32.59	30.32	30.86	35.29
Dry soil + can, gm.	26.15	28.23	26.18	26.95	30.37
Weight of can, gm.	18.86	19.80	18.51	19.92	21.66
Weight of water, gm.	3.65	4.36	4.14	3.91	4.92
Weight of dry soil, gm.	7.29	8.43	7.67	7.03	8.71
% Water content	50.07	51.72	53.98	55.62	56.49



Liquid limit = 53.27

Can no.	1	2
Wet soil + can, gm.	32.24	33.40
Dry soil + can, gm.	29.64	31.18
Weight of can, gm.	19.78	22.85
Weight of water, gm.	2.6	2.22
Weight of dry soil, gm.	9.86	8.33
% Water content	26.37	26.65

$$\text{Plastic limit} = \frac{26.37 + 26.65}{2}$$

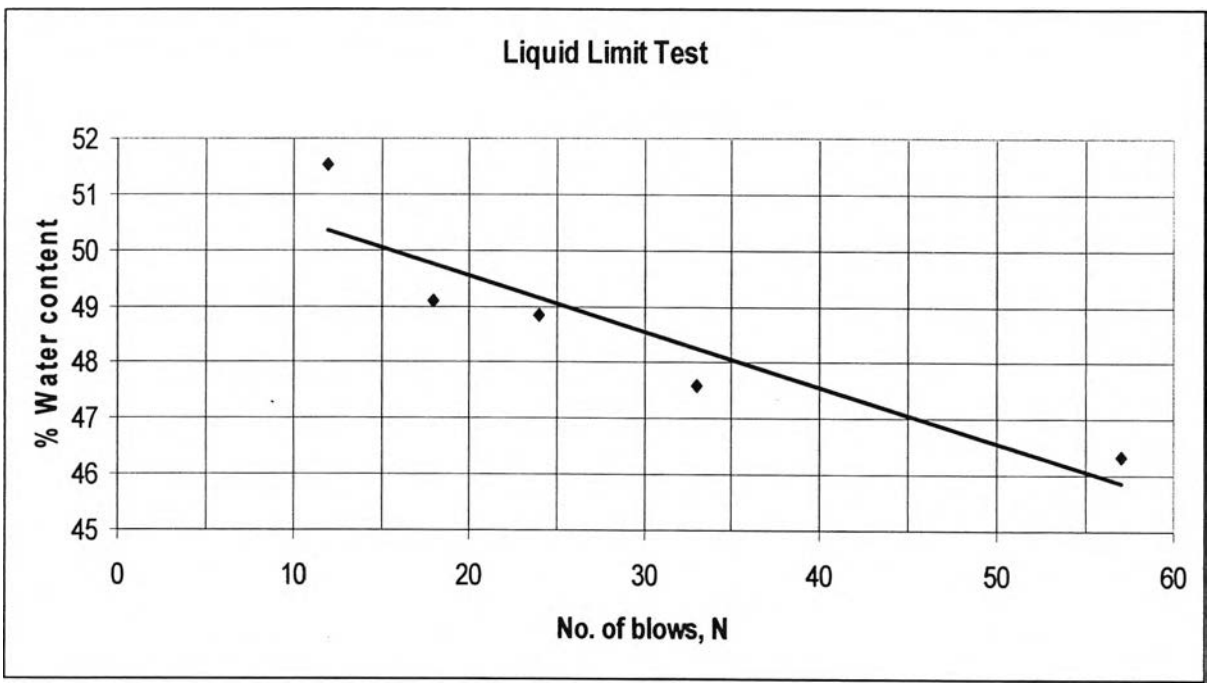
$$= 26.51$$

$$\text{Plastic Index} = 53.27 - 26.51$$

$$= 26.76$$

Siam Magotteaux : Siam Nawaloha = 7 : 3 (Bentonite = 22.88%)

No. of blows, N	57	33	24	18	12
Can no.	1	2	3	4	5
Wet soil + can, gm.	32.14	30.29	37.27	28.67	28.97
Dry soil + can, gm.	27.27	25.58	32.49	24.85	24.43
Weight of can, gm.	16.76	15.68	22.70	17.07	15.62
Weight of water, gm.	4.87	4.71	4.78	3.82	4.54
Weight of dry soil, gm.	10.51	9.90	9.79	7.78	8.81
% Water content	46.34	47.58	48.83	49.10	51.53



Liquid limit = 49.06

Can no.	1	2
Wet soil + can, gm.	30.34	29.00
Dry soil + can, gm.	28.54	26.83
Weight of can, gm.	21.98	18.67
Weight of water, gm.	1.80	2.17
Weight of dry soil, gm.	6.56	8.16
% Water content	27.44	26.59

$$\text{Plastic limit} = \frac{27.44 + 26.59}{2}$$

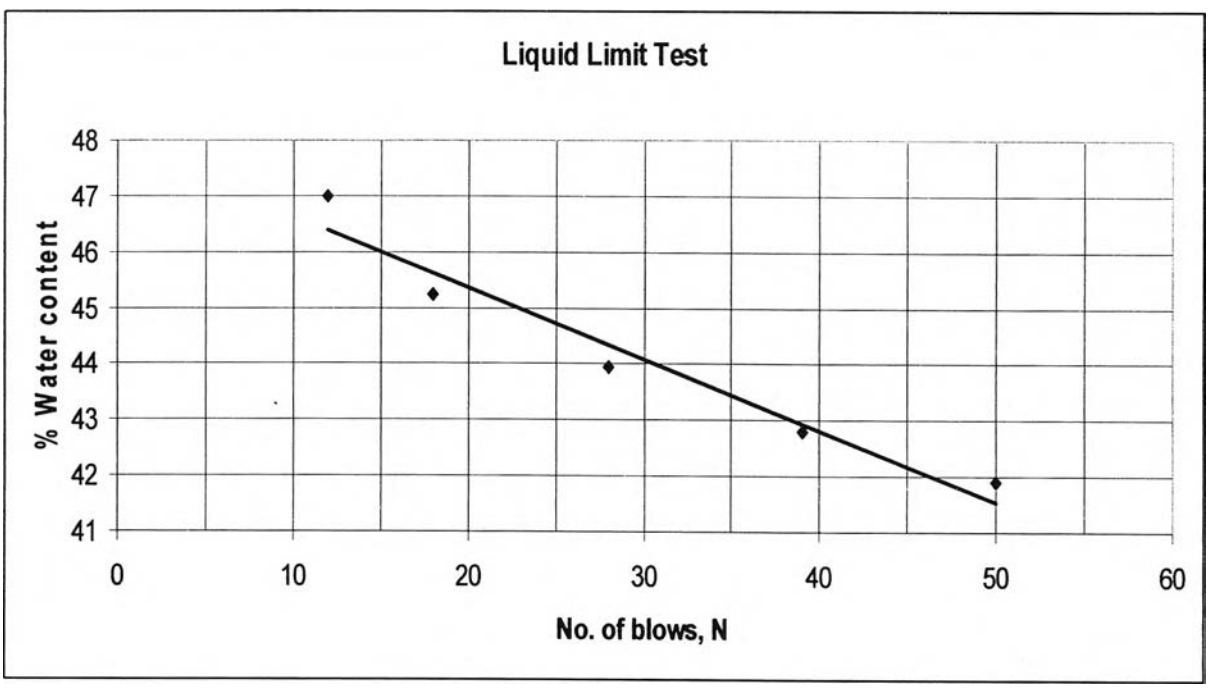
$$= 27.02$$

$$\text{Plastic Index} = 49.06 - 27.02$$

$$= 22.04$$

Siam Magotteaux : Siam Nawaloha = 6 : 4 (Bentonite = 21.24%)

No. of blows, N	50	39	28	18	12
Can no.	1	2	3	4	5
Wet soil + can, gm.	32.12	32.90	33.18	35.79	27.97
Dry soil + can, gm.	28.27	28.70	29.31	31.42	23.85
Weight of can, gm.	19.08	18.89	20.50	21.76	15.08
Weight of water, gm.	3.85	4.2	3.87	4.37	4.12
Weight of dry soil, gm.	9.19	9.81	8.81	9.66	8.77
% Water content	41.89	42.81	43.93	45.24	46.98



Liquid limit = 44.73

Can no.	1	2
Wet soil + can, gm.	32.56	28.68
Dry soil + can, gm.	29.98	26.62
Weight of can, gm.	19.76	18.55
Weight of water, gm.	2.58	2.06
Weight of dry soil, gm.	10.22	8.07
% Water content	25.24	25.53

$$\text{Plastic limit} = \frac{25.24 + 25.53}{2}$$

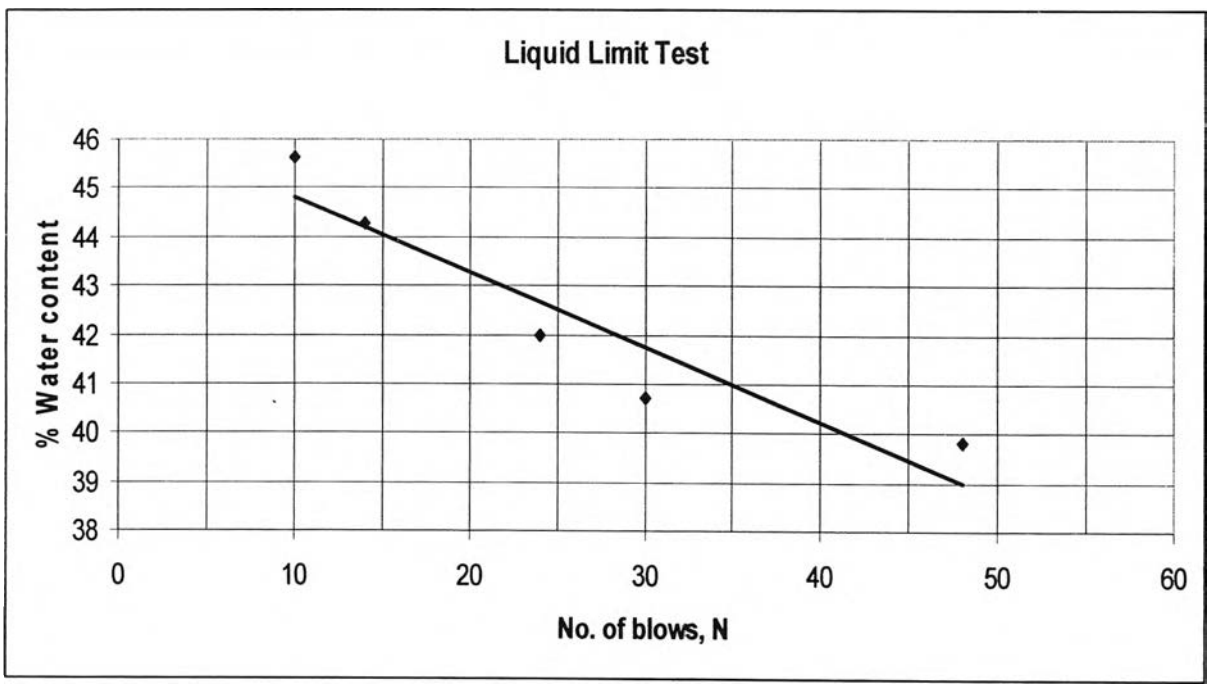
$$= 25.39$$

$$\text{Plastic Index} = 44.73 - 25.39$$

$$= 19.34$$

Siam Magotteaux : Siam Nawaloha = 5 : 5 (Bentonite = 19.60%)

No. of blows, N	48	30	24	14	10
Can no.	1	2	3	4	5
Wet soil + can, gm.	40.73	39.56	40.64	40.50	41.30
Dry soil + can, gm.	36.50	35.29	35.86	35.62	36.64
Weight of can, gm.	25.87	24.80	24.47	24.60	26.43
Weight of water, gm.	4.23	4.27	4.78	4.88	4.66
Weight of dry soil, gm.	10.63	10.49	11.39	11.02	10.21
% Water content	39.79	40.71	41.97	44.28	45.64



Liquid limit = 42.51

Can no.	1	2
Wet soil + can, gm.	35.37	29.23
Dry soil + can, gm.	32.74	27.16
Weight of can, gm.	21.80	18.16
Weight of water, gm.	2.63	2.07
Weight of dry soil, gm.	10.94	9.00
% Water content	24.04	23.00

$$\text{Plastic limit} = \frac{24.04 + 23.00}{2}$$

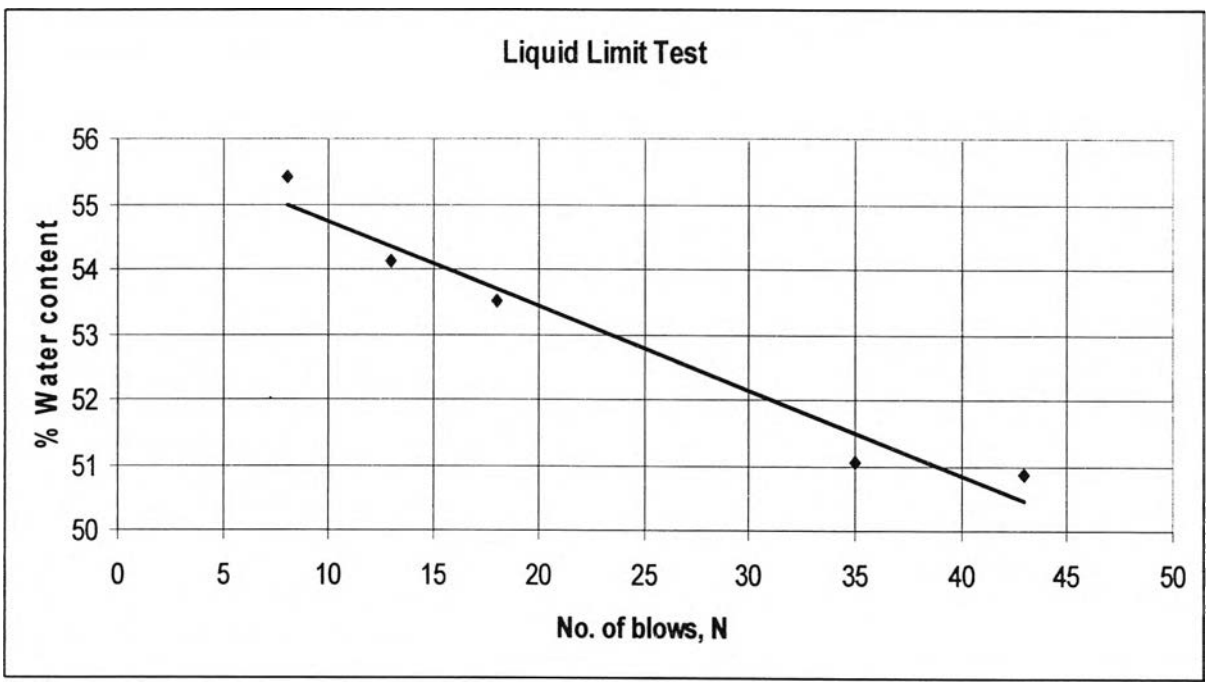
$$= 23.52$$

$$\text{Plastic Index} = 42.51 - 23.52$$

$$= 18.99$$

Siam Magotteaux : Pure Sand = 9 : 1 (Bentonite = 25.03%)

No. of blows, N	43	35	18	13	8
Can no.	1	2	3	4	5
Wet soil + can, gm.	35.08	33.28	34.78	28.50	32.28
Dry soil + can, gm.	29.50	28.91	29.54	23.72	27.67
Weight of can, gm.	18.53	20.35	19.75	14.89	19.35
Weight of water, gm.	5.58	4.37	5.24	4.78	4.61
Weight of dry soil, gm.	10.97	8.56	9.79	8.83	8.32
% Water content	50.87	51.05	53.52	54.13	55.41



Liquid limit = 52.79

Can no.	1	2
Wet soil + can, gm.	28.35	27.09
Dry soil + can, gm.	26.54	24.87
Weight of can, gm.	19.88	16.79
Weight of water, gm.	1.81	2.22
Weight of dry soil, gm.	6.66	8.08
% Water content	27.18	27.48

$$\text{Plastic limit} = \frac{27.18 + 27.48}{2}$$

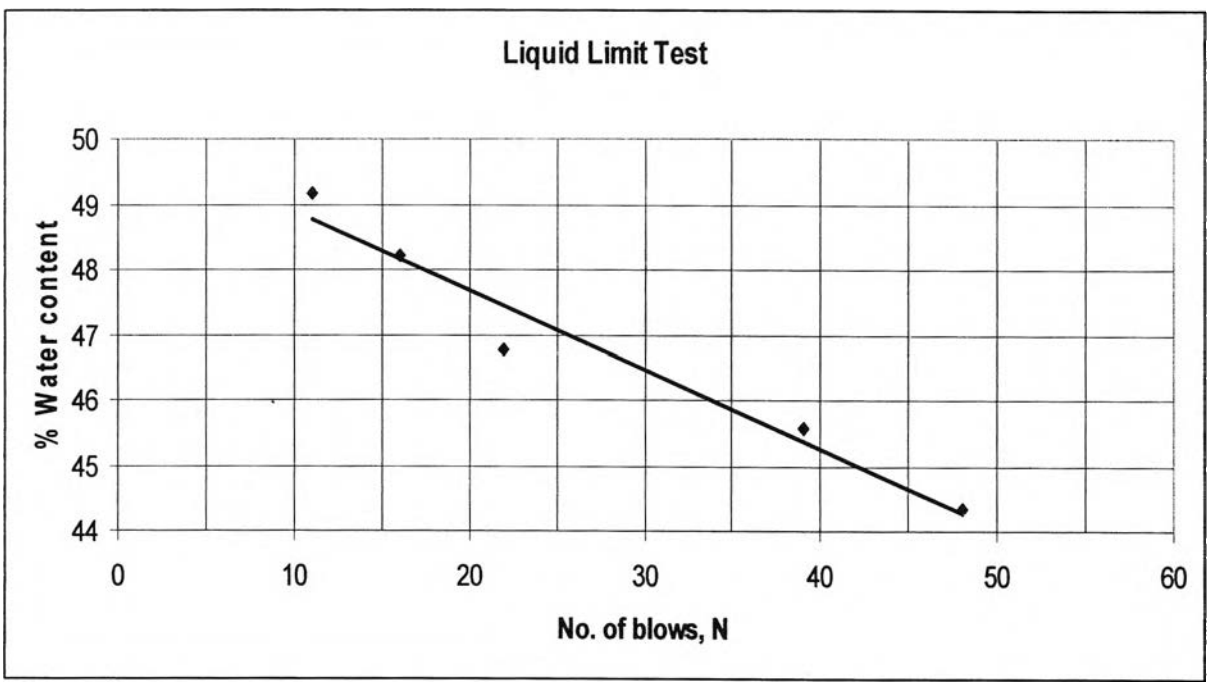
$$= 27.33$$

$$\text{Plastic Index} = 52.79 - 27.33$$

$$= 25.46$$

Siam Magotteaux : Pure Sand = 8 : 2 (Bentonite = 22.25%)

No. of blows, N	48	39	22	16	11
Can no.	1	2	3	4	5
Wet soil + can, gm.	37.37	37.18	30.29	30.74	36.34
Dry soil + can, gm.	32.63	32.45	26.23	26.37	31.67
Weight of can, gm.	21.94	22.07	17.55	17.31	22.17
Weight of water, gm.	4.74	4.73	4.06	4.37	4.67
Weight of dry soil, gm.	10.69	10.38	8.68	9.06	9.5
% Water content	44.34	45.57	46.77	48.23	49.16



Liquid limit = 47.08

Can no.	1	2
Wet soil + can, gm.	30.15	31.79
Dry soil + can, gm.	27.94	29.54
Weight of can, gm.	19.53	20.58
Weight of water, gm.	2.21	2.25
Weight of dry soil, gm.	8.41	8.96
% Water content	26.28	25.11

$$\text{Plastic limit} = \frac{26.28 + 25.11}{2}$$

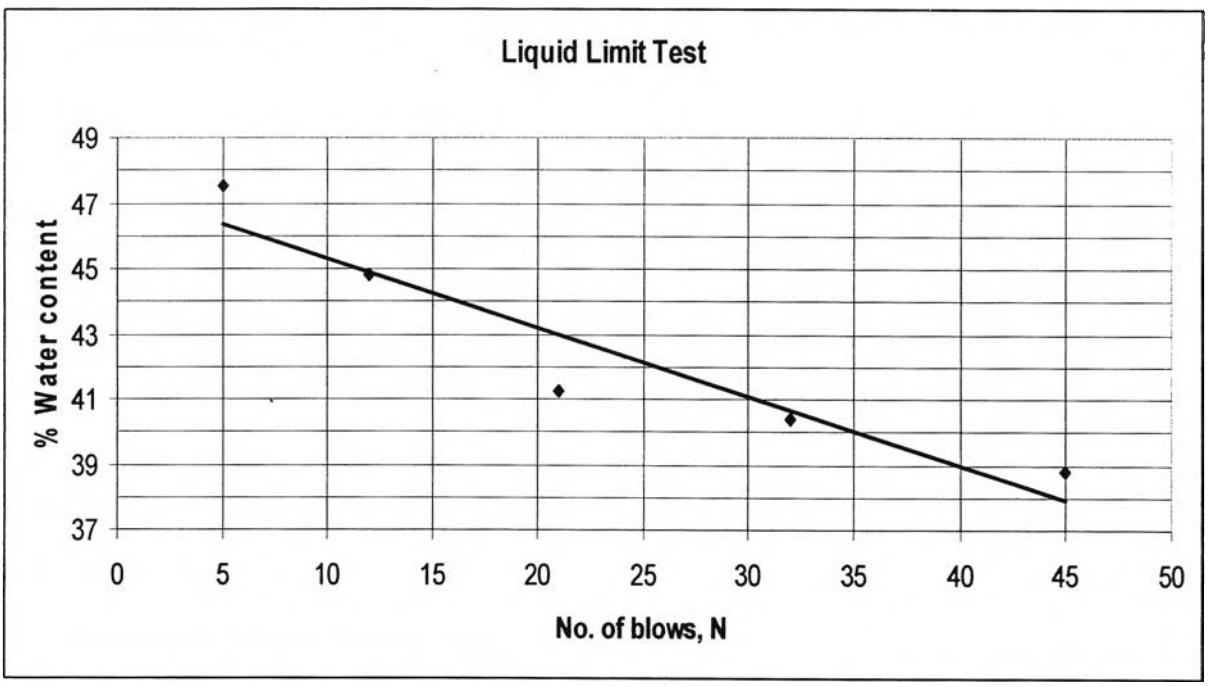
$$= 25.70$$

$$\text{Plastic Index} = 47.08 - 25.70$$

$$= 21.38$$

Siam Magotteaux : Pure Sand = 7 : 3 (Bentonite = 19.47%)

No. of blows, N	45	32	21	12	5
Can no.	1	2	3	4	5
Wet soil + can, gm.	33.17	30.05	34.02	36.38	33.10
Dry soil + can, gm.	30.03	26.44	29.89	31.95	29.54
Weight of can, gm.	21.94	17.50	19.87	22.06	22.05
Weight of water, gm.	3.14	3.61	4.13	4.43	3.56
Weight of dry soil, gm.	8.09	8.94	10.02	9.89	7.49
% Water content	38.81	40.38	41.22	44.79	47.53



Liquid limit = 42.12

Can no.	1	2
Wet soil + can, gm.	31.10	28.71
Dry soil + can, gm.	29.22	26.49
Weight of can, gm.	21.37	17.30
Weight of water, gm.	1.88	2.22
Weight of dry soil, gm.	7.85	9.19
% Water content	23.95	24.16

$$\text{Plastic limit} = \frac{23.95 + 24.16}{2}$$

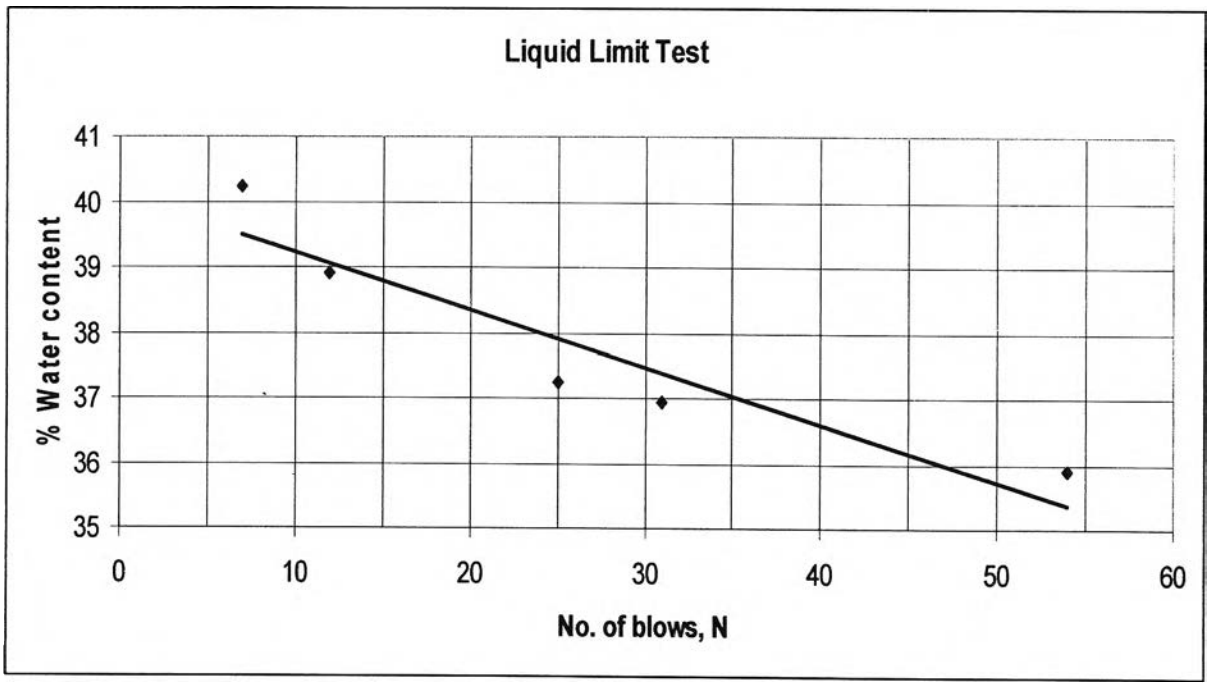
$$= 24.06$$

$$\text{Plastic Index} = 42.12 - 24.06$$

$$= 18.06$$

Siam Magotteaux : Pure Sand = 6 : 4 (Bentonite = 16.69%)

No. of blows, N	54	31	25	12	7
Can no.	1	2	3	4	5
Wet soil + can, gm.	34.34	28.47	33.47	35.84	34.18
Dry soil + can, gm.	30.64	24.81	30.39	32.45	29.19
Weight of can, gm.	20.33	14.90	22.12	23.74	16.79
Weight of water, gm.	3.7	3.66	3.08	3.39	4.99
Weight of dry soil, gm.	10.31	9.91	8.27	8.71	12.4
% Water content	35.89	36.93	37.24	38.92	40.24



Liquid limit = 37.91

Can no.	1	2
Wet soil + can, gm.	29.11	30.50
Dry soil + can, gm.	27.42	28.75
Weight of can, gm.	19.33	20.56
Weight of water, gm.	1.69	1.75
Weight of dry soil, gm.	8.09	8.19
% Water content	20.89	21.37

$$\text{Plastic limit} = \frac{20.89 + 21.37}{2}$$

$$= 21.13$$

$$\text{Plastic Index} = 37.91 - 21.13$$

$$= 16.78$$

Siam Magotteaux : Pure Sand = 5 : 5 (Bentonite = 13.91%)

Mixed sand with this ratio is considered as non-plastic, so it can't find LL. and PL.

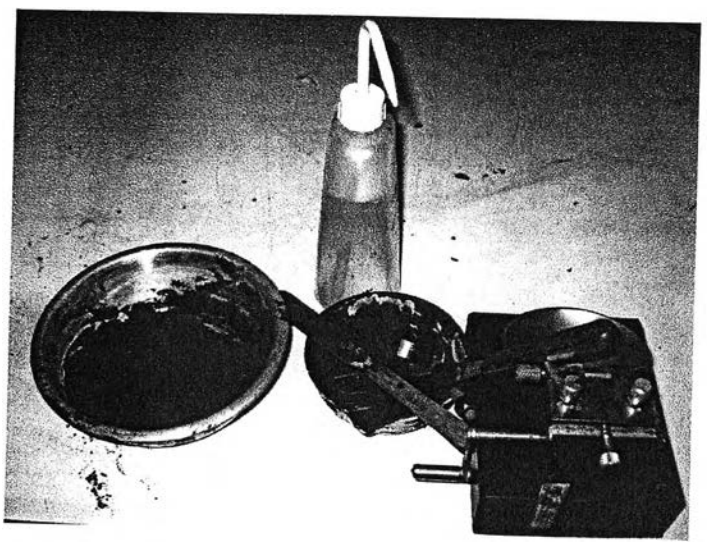


Figure D.1 Liquid Limit Device

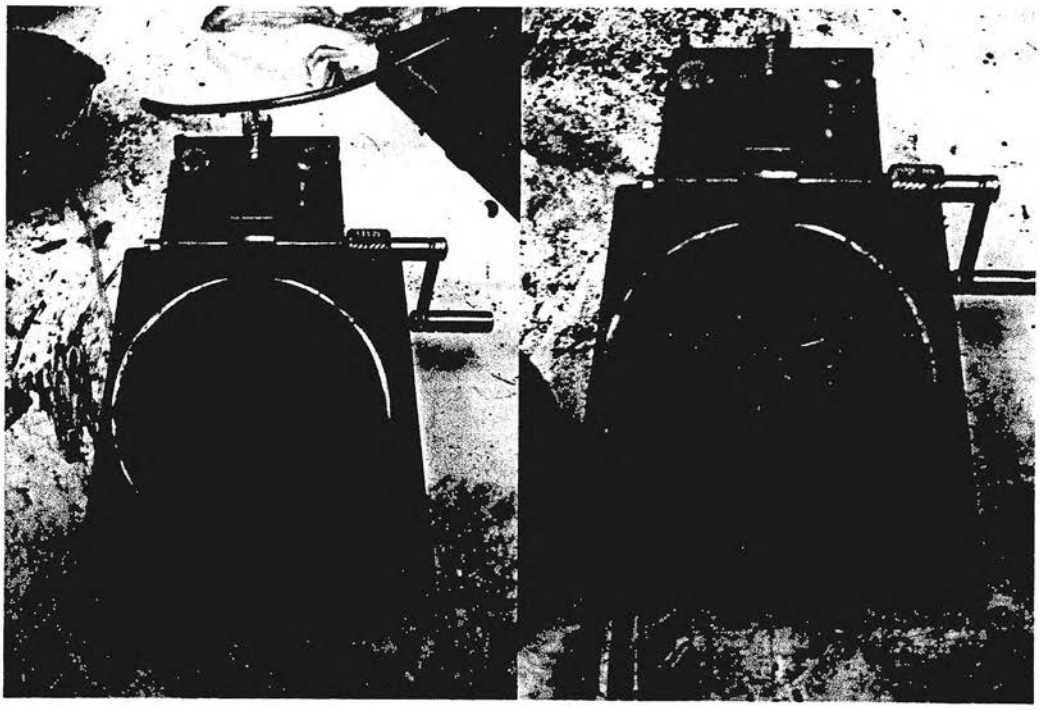


Figure D.2-D.3 Liquid Limit Test

BIOGRAPHY

Mr. Pongsabutt Auychaiwatt was born on October 1, 1980. He received his Bachelor's Degree in Environmental Engineering from faculty of Engineering, Chulalongkorn University in 2002. He persued his Master Degree study in the International Postgraduate Program in Environmental Management, Inter-Department of Environmental Management, Chulalongkorn University, Bangkok, Thailand in May 2002. He was awarded Master Degree of Science in Environmental Management in May 2004.