



## REFERENCES

- Alba, N., S. Gasso, T. Lacorte, and J. M. Baldasano. 1997. Characterization of municipal solid waste incinerator residues from facilities with different air pollution control systems. *J. of the Air and Waste Management Association* 47: 1170-1179.
- Ali, T. M., and W. F. Chang. 1994. Strength properties of cement-stabilized municipal solid waste incinerator ash masonry bricks. *ACI Materials J.* 91: 256-263.
- American Coal Fly Ash. 1995. *Fly ash facts for highway engineers*. Washington D.C.: Federal Highway Administration, Department of Transportation. (Mimeographed)
- Ampadu, K. O., and K. Torii. 2001. Characterization of ecocement pastes and mortars produced from incinerated ashes. *Cement and Concrete Research* 31: 431-436.
- ASTM C109. 1996. Standard test method for compressive strength of hydraulic cement mortars (Using 2-in. or 50-mm cube specimens). ASTM C109-95. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C114. 1996. Standard test methods for chemical analysis of hydraulic cement. ASTM C114-94. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C136. 1996. Standard test method for sieve analysis of fine and coarse aggregates. ASTM C136-95a. *Annual Book of ASTM Standards*. Vol. 04.02.
- ASTM C150. 1996. Standard specification for Portland cement. ASTM C150-95a. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C187. 1996. Standard test method for normal consistency of hydraulic cement. ASTM C187-86. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C188. 1996. Standard test method for density of hydraulic cement. ASTM C188-95. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C191. 1996. Standard test method for time of setting of hydraulic cement by vicat needle. ASTM C191-92. *Annual Book of ASTM Standards*. Vol. 04.01.
- ASTM C204. 1996. Standard test method for fineness of hydraulic cement by air permeability apparatus. ASTM C204-96. *Annual Book of ASTM Standards*. Vol. 04.01.

- ASTM C311. 1996. Standard test methods for sampling and testing fly ash or natural pozzolans for use as a mineral admixture in Portland-cement concrete. ASTM C311-96a. *Annual Book of ASTM Standards*. Vol. 04.02.
- ASTM C618. 1996. Standard Specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete. ASTM C618-96. *Annual Book of ASTM Standards*. Vol. 04.02.
- Bentz, D. P., P. E. Stutzman, C. J. Haecker, and S. Remond. 1999. SEM/X-ray imaging of cement-based materials. *Proceeding of the 7<sup>th</sup> Euroseminar on Microscopy Applied to Building Materials*, pp. 457-446. June 19-July 2. Delft, The Netherlands: Delft University of Technology.
- Berg, E. R., and J. A. Neal. 1998. Municipal solid waste bottom ash as portland cement concrete ingredient. *J. of Materials in Civil Engineering* 10: 168-173.
- Berry, E. E., R. T. Hemmings, M-H. Zhang, B. J. Cornelius, and D. M. Golden. 1994. Hydration in high-volume fly ash concrete binders. *ACI Materials J.* 91: 382-389.
- Berry, E. E., and V. M. Malhotra. 1987. Chapter 2: Fly ash in concrete. In V. M. Malhotra (ed.), *Supplementary cementing materials for concrete*, pp. 36-79. Ottawa, Canada: Energy, Mines, and Resources Canada, Canada Centre for Mineral and Energy Technology.
- Bilodeav, A., V. Sivasundaram, K. E. Painter, and V. M. Molhotra. 1994. Durability of concrete incorporating high volumes of fly ash from sources in the U.S. *ACI Materials J.* 91: 3-12.
- Buchholz, B. A., and S. Landsberger. 1995. Leaching dynamics studies of municipal solid waste incinerator ash. *J. of the Air and Waste Management Association* 45: 579-590.
- Cheng, K. Y., and P. Bishop. 1992. Metals distribution in solidified/stabilized waste forms after leaching. *Hazardous Waste and Hazardous Materials* 9: 163-171.
- Chichester, D. L., and S. Landsberger. 1996. Determining of the leaching dynamics of metals from municipal solid waste incinerator fly ash using a column test. *J. of the Air and Waste Management Association* 46: 643-649.
- Cline, J. A., M. Bijl, and A. Torrenuera. 2000. Coal fly ash as a soil conditioner for field crops in southern Ontario. *J. Environmental Quality* 29: 1982-1989.
- CUR. 1992. *Fly ash as addition to concrete*. Rotterdam, The Netherlands: A. A. Balkema.

- Ecke, H., H. Sankanakura, T. Matsuto, N. Tanaka, and A. Lagerkvist. 2000. State-of-the-art treatment processes for municipal solid waste incineration residues in Japan. *Waste Management and Research* 18: 41-51.
- Fermo, P., and others. 1999. The analytical characterization of municipal solid waste incinerator fly ash: Methods and preliminary result. *Fresenius J. Analytical Chemistry* 365: 666-673.
- Fermo, P., F. Cariati, A. Pozzi, M. Tettamanti, E. Collina, and D. Pitea. 2000. Analytical characterization of municipal solid waste incinerator fly ash part II. *Fresenius J. Analytical Chemistry* 366: 267-272.
- Goh, Anthony T. C., and J. H. Tay. 1993. Municipal solid-waste incinerator fly ash for geotechnical applications. *J. of Geotechnical Engineering* 119: 811-825.
- Goldin, A., C. Bigelow, and P. L. M. Veneman. 1992. Concentrations of metals in ash from municipal solid combustors. *Chemosphere* 24: 271-280.
- Gorman, J. M., J. C. Sencindiver, D. J. Horvath, R. N. Singh, and R. F. Keefer. 2000. Erodibility of fly ash used as a topsoil substitute in mineland reclamation. *J. Environmental Quality* 29: 805-811.
- Hamernik, J. D., and G. C. Frantz. 1991a. Physical and chemical properties of municipal solid waste fly ash. *ACI Material J.* 88: 294-301.
- Hamernik, J. D., and G. C. Frantz. 1991b. Strength of concrete containing municipal solid waste fly ash. *ACI Materials J.* 88: 508-517.
- Hongpatanporn, U. 1989. *Strength development of Portland cement mixed with fly ash and rice husk ash.* Master's Thesis, Department of Civil Engineering, Graduate School, Chulalongkorn University.
- Jaturapitakkul, C. 1993. *Utilization of fly ash in concrete.* Doctoral Dissertation, Department of Civil and Environmental Engineering, New Jersey Institute of Technology, New Jersey.
- Jaturapitakkul, C., and others. 2001. Chemical and physical properties of fly ash. *Seminar: The Utilization of Fly Ash in Concrete Applications*, pp. 7-9. February 17. Bangkok: EGAT.
- Kirby, C. S., and J. D. Rimstidt. 1993. Mineralogy and surface properties of municipal solid waste ash. *Environmental Science and Technology* 27: 652-660.

- LaGrega, M. D., P. L. Buckingham, J. C. Evans, and Environmental Resources Management. 2001. *Hazardous waste management*. 2<sup>nd</sup> ed. Singapore: McGraw-Hill.
- Lav, A. H., and M. A. Lav. 2000. Microstructural development of stabilized fly ash as pavement base material. *J. of Materials in Civil Engineering* 12: 157-163.
- Lea, F. M. 1971. *The chemical of cement and concrete*. 3<sup>rd</sup> ed. New York: Chemical Publishing.
- Mangialardi, T., L. Piga, F. Schena, and P. Sirini. 1998. Characteristics of MSW incinerator ash for use in concrete. *Environmental Engineering Science* 15: 291-297.
- Ministry of Industry. 2002. *Notification of Ministry of Industry No. 6 B.E. 2540 (1997)*[Online]. Available from: <http://www.diw.go.th/law/nmoi6y40.html> [2002, June 22]
- Morf, L. S., P. H. Brunner, and S. Spaun. 2000. Effect of operating conditions and input variations on the partitioning of metals in a municipal solid waste incinerator. *Waste Management and Research* 18: 4-15.
- Neville, A. M. 1995. *Properties of concrete*. 4<sup>th</sup> ed. London: Pitman.
- Pal Consultant. 1998. *The study for reduce, reuse, and recycling solid waste in Phuket*. Phuket: Phuket Municipality. (Mimeographed)
- PC Montenev. 2001. *Analysis report for statistical data of Phuket waste stream and heavy metal concentrations in Phuket bottom ash*. Bangkok: PC Montenev Co. Ltd. (Unpublished Manuscript)
- Phuket Municipality. 2002. *Incinerator Phuket plant municipality*[Online]. Available from: <http://www.phuketcity.go.th>[2002, March 8]
- Plüss, A., and R. E. Ferrell, JR., 1991. Characterization of lead and other heavy metals in fly ash from municipal waste incinerators. *Hazardous Waste and Hazardous Materials* 8: 275-292.
- Rachakornkij, M. 2000. *Utilization of municipal solid waste incinerator fly ash in cement mortars*. Doctoral Dissertation, Department of Civil and Environmental Engineering, New Jersey Institute of Technology, New Jersey.
- Rashid, R. A., and G. C. Frantz. 1992. MSW incinerator ash as aggregate in concrete and masonry. *J. of Materials in Civil Engineering* 4: 353-368.
- Rebeiz, K. S., and K. L. Mielich. 1995. Construction use of municipal-solid-waste ash. *J. of Energy Engineering* 121: 2-13.

- Remond, S., P. Pimienta, and D. P. Bentz. 2002. Effects of the incorporation of municipal solid waste incineration fly ash in cement pastes and mortars I. Experimental study. *Cement and Concrete Research* 32: 303-311.
- Richers, U., and L. Birnbaum. 1997. Characterization by physical measuring methods of filter ashes from municipal solid waste incineration plants. *Hungarian Journal of Industrial Chemistry* 25: 229-232.
- Shieh, C. S. 2001. *Fate of municipal waste combustion ash in the environment*. Melbourne, Florida: Research Center for Waste Utilization, Florida Institute of Technology. (Unpublished Manuscript)
- Tchobanoglous, G., H. Theisen, and S. Vigil. 1993. *Integrated solid waste management*. Singapore: McGraw-Hill.
- Triano, J. R., and G. C. Frantz. 1992. Durability of MSW fly-ash concrete. *J. of Materials in Civil Engineering* 4: 369-384.
- U.S. Environmental Protection Agency. 2002. *SW-846: Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*[Online]. Available from: <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm>[2002, February 12]
- Wadge, A., and M. Hutton. 1987. The leachability and chemical speciation of selected trace elements in fly ash from coal combustion and refuse incineration. *Environmental Pollution* 48: 85-99.
- Webster, M. T., and R. C. Loehr. 1996. Long-term leaching of metals from concrete products. *J. of Environmental Engineering* 122: 714-721.
- Wesche, K., ed. 1991. *Fly ash in concrete properties and performance*. London: E&FN SPON.
- Zevenbergen, C., T. Vander Wood, J. P. Bradley, P.F.C.W. Van Der Broeck, A. J. Orbons, and L. P. Van Reeuwijk. 1994. Morphological and chemical properties of MSWI bottom ash with respect to the glassy constituents. *Hazardous Waste and Hazardous Materials* 11: 371-383.

## **APPENDICES**

## APPENDIX A

**Table A-1 Properties of MSW in Phuket in 1992**

Component	Percent by weight	
	Average	Range
Moisture content	42.42	33.30 - 67.16
Volatile solids	27.87	8.03 - 45.00
Ash content	22.71	17.73 - 28.03
Heating value*	4791	4304 - 5130
Low calorific value**	2022	1251 - 2826

**Note:** \* Dry solid calorific value (kCal/kg)

\*\* Low solid calorific value (kCal/kg)

**Source:** Pal Consultants, 1998

**Table A-2 Physical Compositions of MSW in Phuket in 1992**

Component	Percent by weight	
	Average	Range
Food and fruit wastes	20.75	12.16 - 27.61
Paper and cardboard	17.53	8.26 - 24.00
Plastic	13.26	4.17 - 26.20
Rubber	0.74	0.31 - 2.38
Leather	4.41	1.04 - 10.16
Textile	4.56	0.80 - 9.83
Wood	13.67	7.50 - 21.74
Glass	4.85	2.86 - 10.96
Metal	4.11	0.44 - 13.36
Ceramic	3.23	1.06 - 9.16
Others	14.91	10.44 - 19.94
Specific weight (kg/m <sup>3</sup> )	210	167 - 257

**Source:** Pal Consultants, 1998

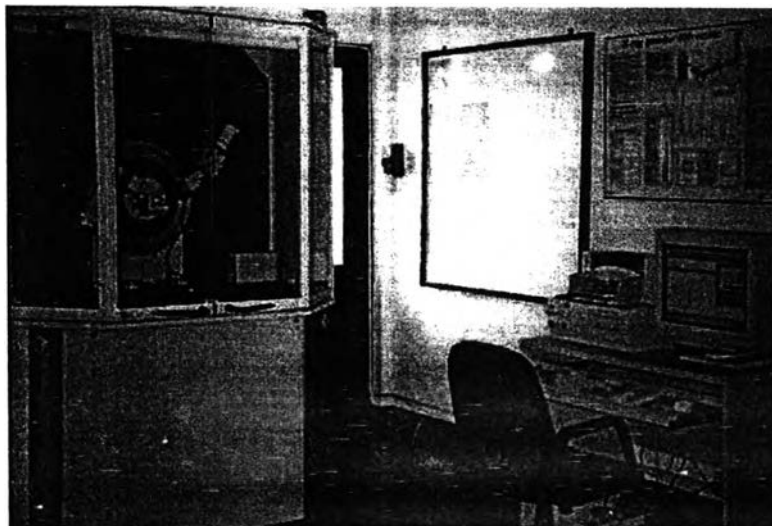
**Table A-3** The statistical amounts of the incinerated waste and the total solid residues from the phuket's plant when it was stated up.

Operational Month	Amount of Waste* (tons/day)	Amount of Solid Residues	
		Bottom Ash (tons/day)	Fly Ash (tons/day)
June, 2000	161.03	31.53	8.12
July, 2000	196.73	63.37	8.10
August, 2000	225.95	42.52	5.45
September, 2000	215.53	49.60	5.07
October, 2000	225.76	52.59	5.88
November, 2000	235.63	50.87	11.71
December, 2000	256.76	83.43	18.47
January, 2001	241.21	42.33	4.64
February, 2001	251.35	73.39	9.25
March, 2001	246.31	53.22	5.39
April, 2001	230.32	60.53	7.86
May, 2001	240.86	61.96	10.20
June, 2001	240.33	74.02	5.72
July, 2001	239.33	55.62	6.50
August, 2001	227.89	53.91	6.40
September, 2001	223.46	54.80	5.84
October, 2001	232.17	55.76	7.07
November, 2001	233.49	49.75	6.14
<b>Average</b>	<b>232.33</b>	<b>56.37</b>	<b>7.41</b>

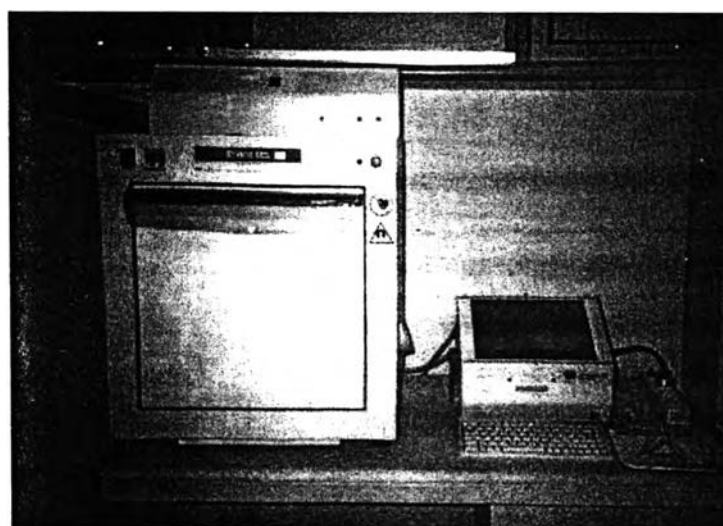
**Note:** \* not include 13.7 percent of moisture in the waste

**Source:** PC Montenegro, 2001



**APPENDIX B**

**Figure B-1** Bruker Powder X-ray Diffraction Spectrometer Model D8 Advance



**Figure B-2** The Microwave Digestion and Extraction Apparatus Model ETHOS SEL

## APPENDIX C

**Table C-1** Compressive Strengths at Different Ages of Mortars Containing Different Percentages of Phuket Fly Ash Replacement

Sample No.	Compressive Strength (ksc)						
	1-day	3-day	7-day	14-day	28-day	45-day	60-day
F00	150	223	299	306	317	321	326
F10	126	187	267	283	294	304	313
F15	122	181	250	271	288	293	310
F25	108	143	177	230	247	257	274

**Note:** Each reported value is an average of 3 mortar cubes.

**Table C-2** Relative Compressive Strengths of Phuket Fly Ash Mortars

Sample No.	Relative Compressive Strength (%)						
	1-day	3-day	7-day	14-day	28-day	45-day	60-day
F00	100	100	100	100	100	100	100
F10	83.9	83.8	89.4	92.5	92.7	94.6	95.9
F15	81.3	81.1	83.8	88.4	90.9	91.2	95.0
F25	71.6	63.8	59.2	75.2	78.0	80.1	84.2

**Table C-3** Relative Compressive Strengths of Phuket Fly Ash Mortars

Sample No.	Relative Compressive Strength (%)							
	1-day	3-day	7-day	14-day	28-day	60-day	90-day	180-day
M00	157	230	273	313	350	380	392	429
M10	145	233	297	316	373	437	460	488
M15	137	235	265	292	366	405	436	442
M20	140	201	247	308	343	401	453	482
M30	122	175	194	266	306	368	385	405

**Note:** Adapted from Hongpatanporn, 1990

## BIOGRAPHY



Miss Podjane Inthasaro was born on January 24, 1979 in Songkhla, Thailand. She attended Hadyaiwittayalai School in Songkhla and graduated in 1995. She received her Bachelor's Degree in Civil Engineering from Faculty of Engineering, Prince of Songkla University in 2000. She pursued her Master Degree studies in the International Postgraduate Programs in Environmental Management, Inter-Department of Environmental Management, Chulalongkorn University, Bangkok, Thailand in May 2000. She finished her Master Degree of Science in Environmental Management in October 2002.