Early-Age Heat and Temperature Profiles in Concretes Made With High Proportions of GGBS and Fly Ash in the Cement Binders

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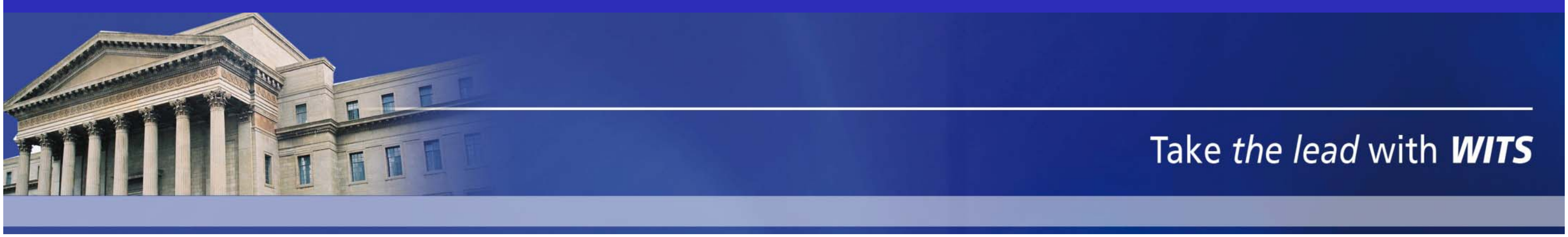
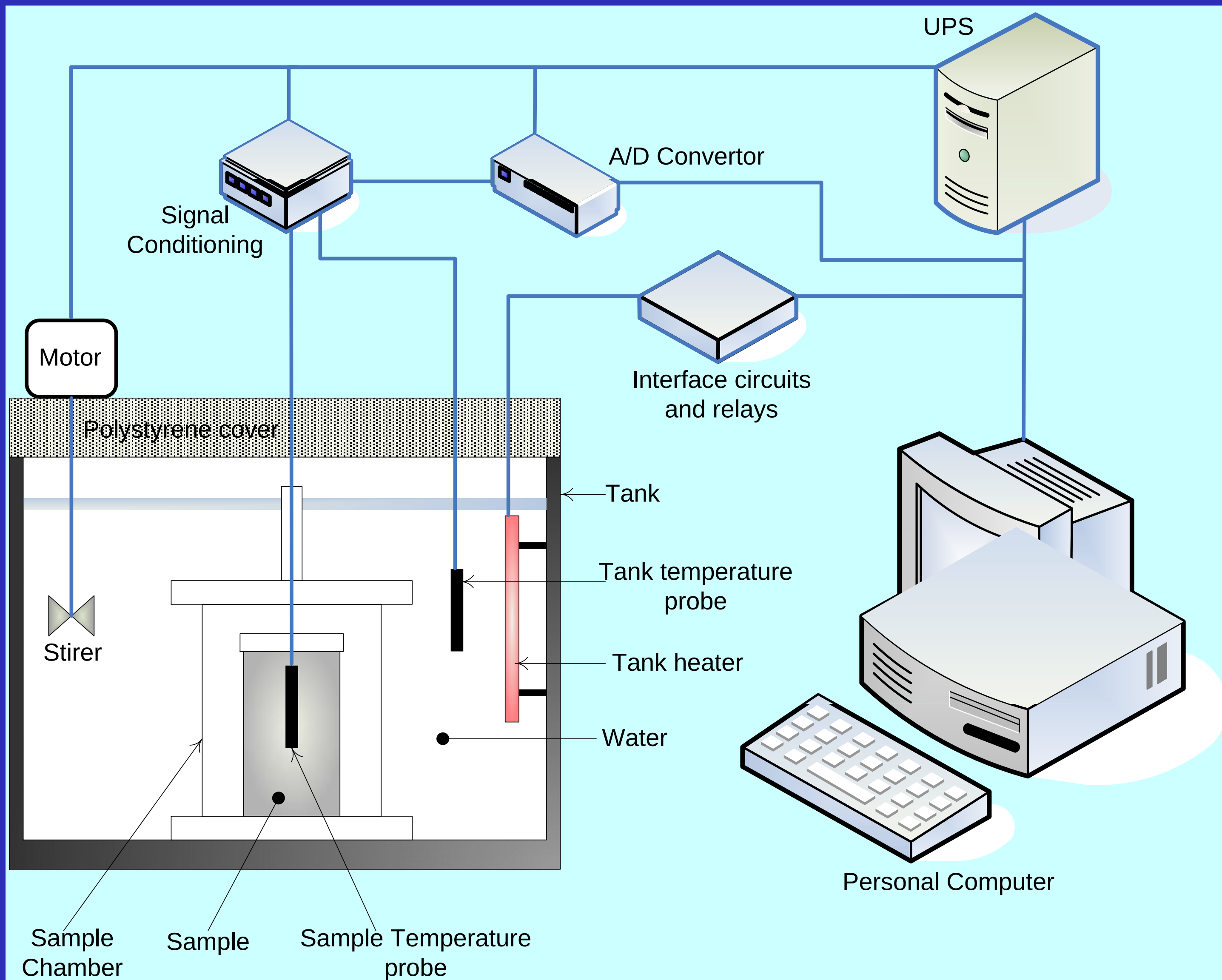
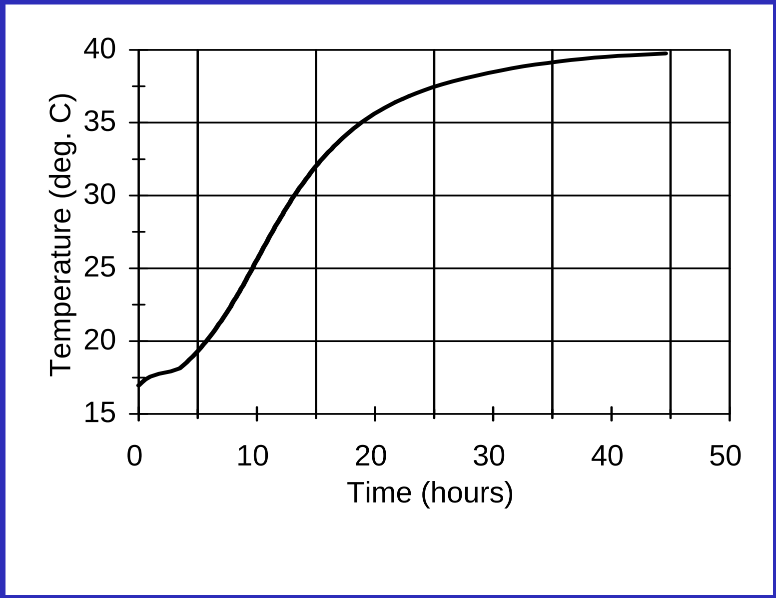


Overview

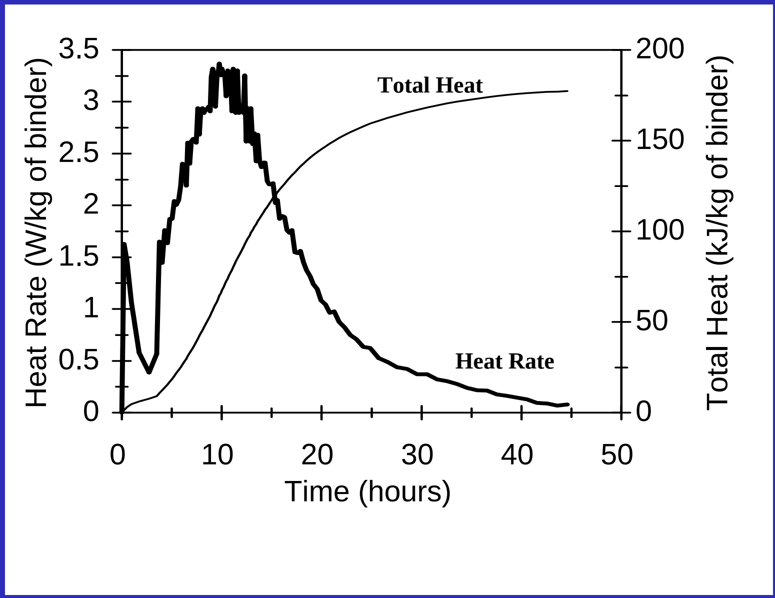
- Measuring the rate of heat evolution from cement
- Form of expression of the heat rate function
- Effect of cement extenders on measured heat rate
- Brief description of the Wits University temperature prediction model
- Effect of cement extenders on temperature development in a large concrete element

WITS Adiabatic Calorimeter





$$q_t = C_p . (T_t - T_o) \cdot \frac{m_s}{m_c}$$



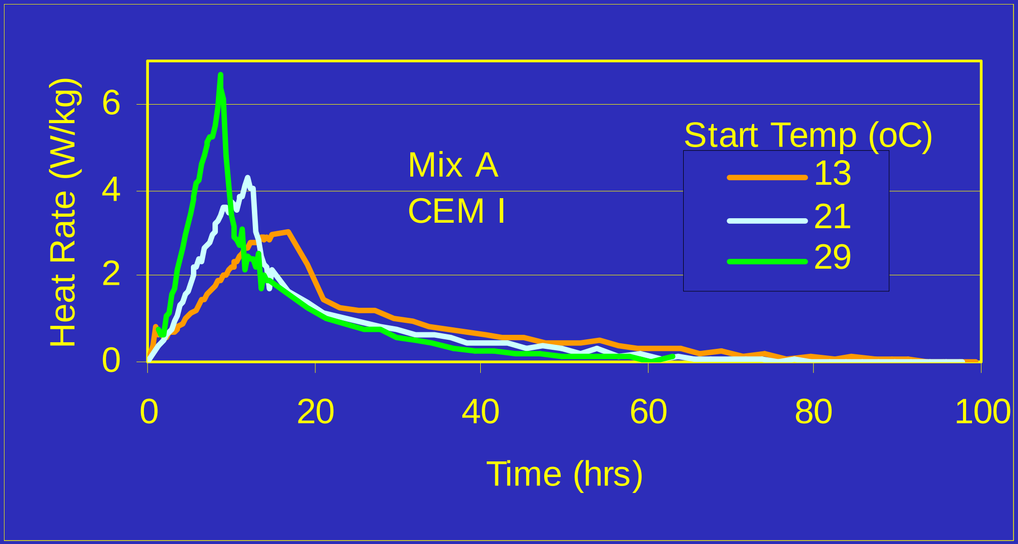
Normalise the
heat rate curve to

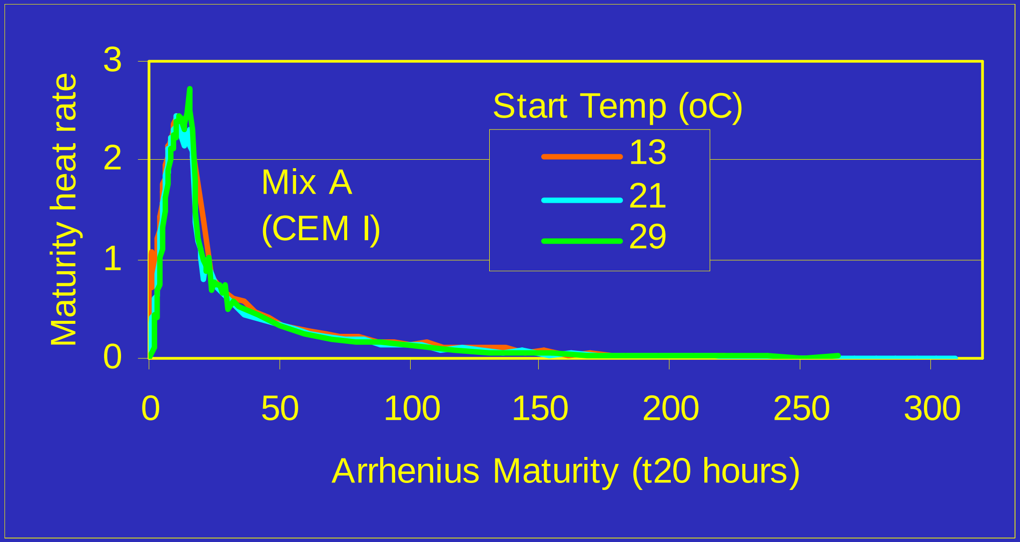
$$\frac{\partial q}{\partial M}$$

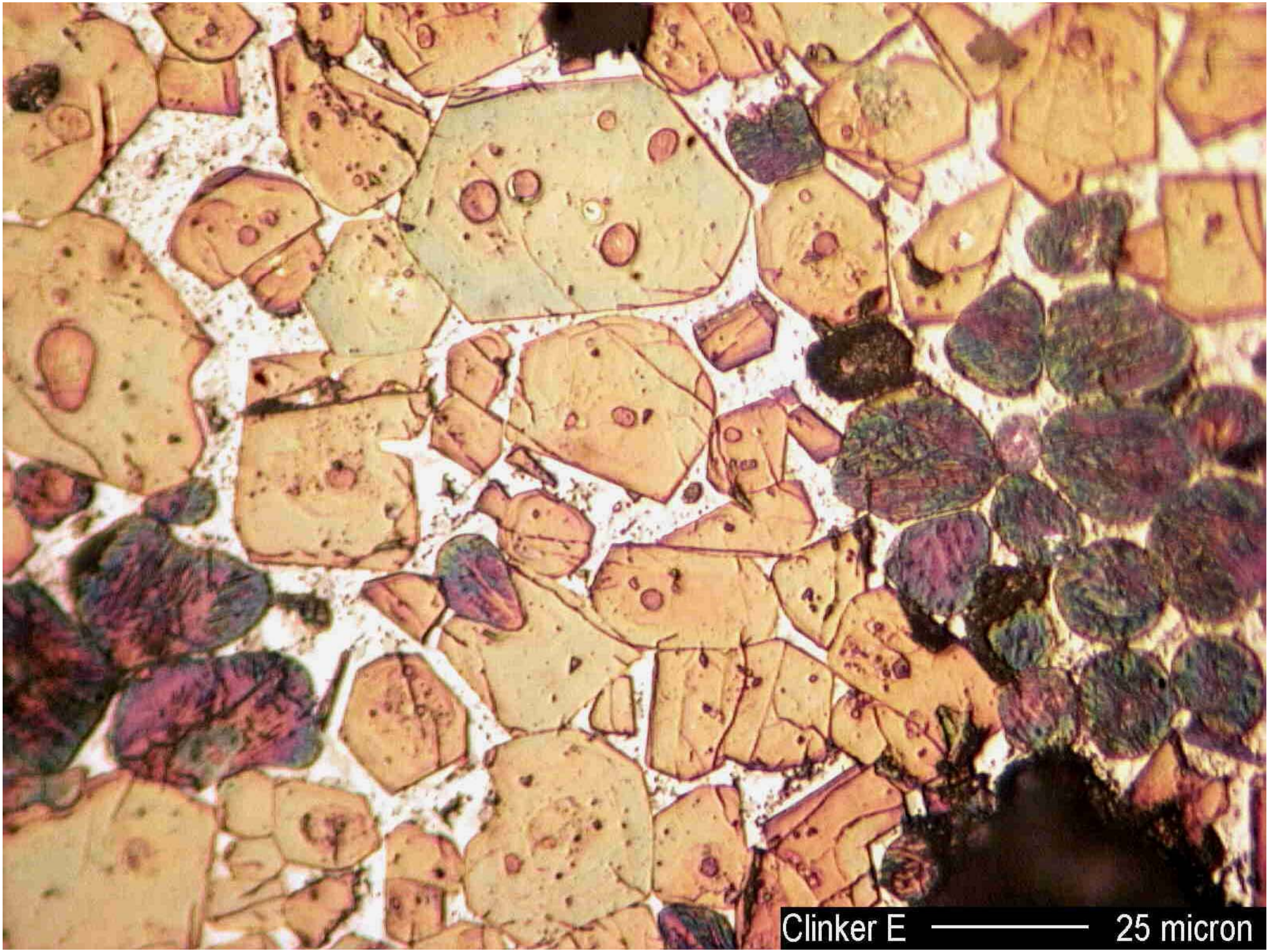
as a function of Maturity
and convert to clock time by

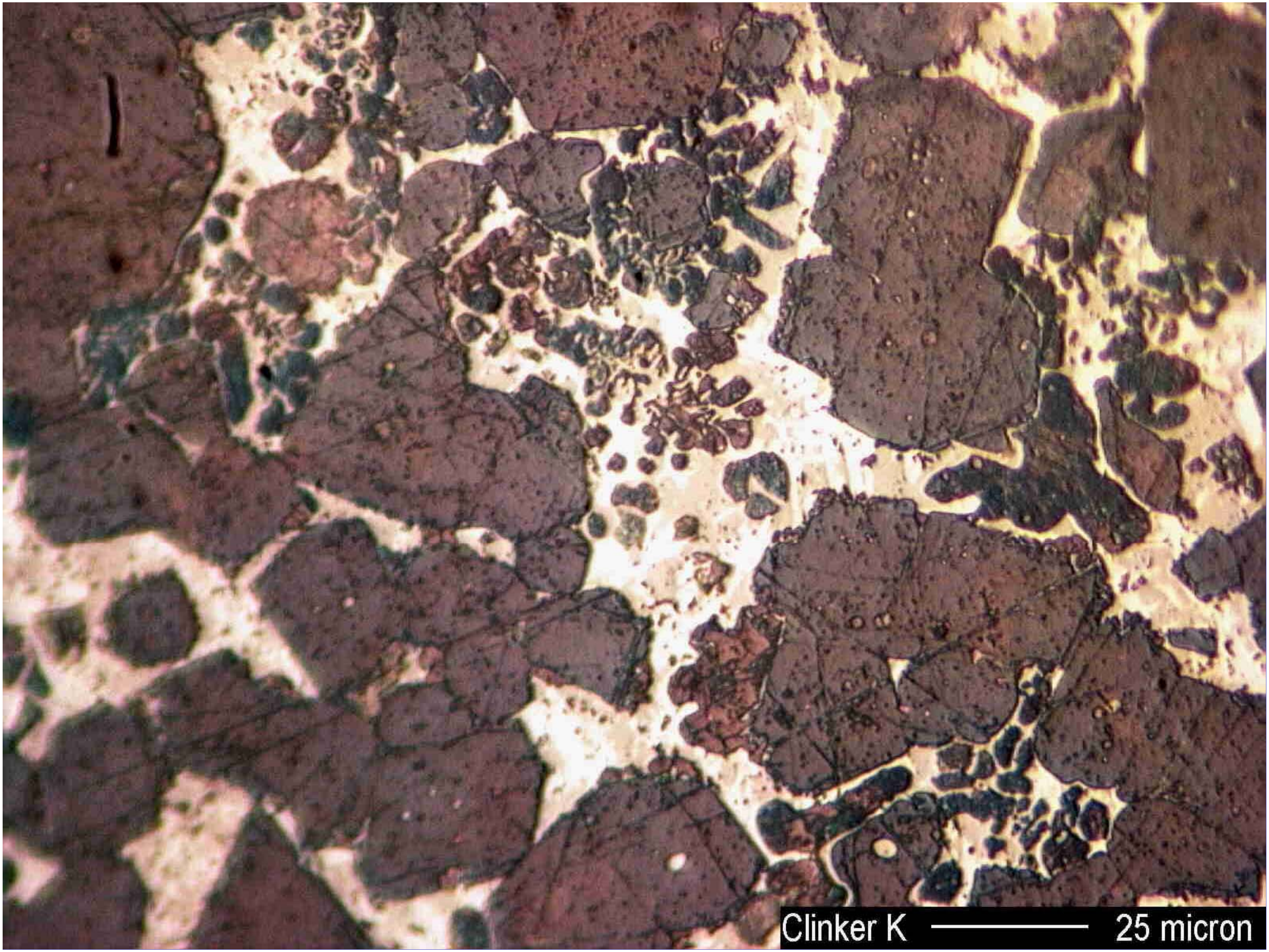
$$\frac{\partial q}{\partial t} = \frac{\partial q}{\partial M} \cdot \frac{dM}{dt}$$

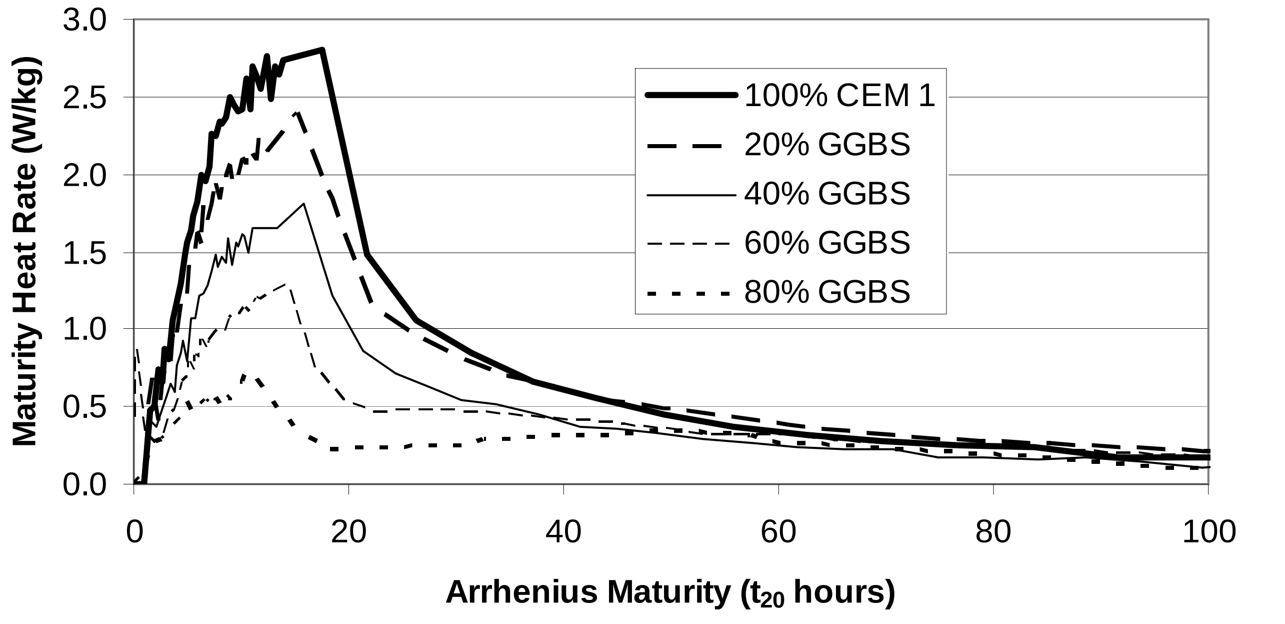
Arhenius MaturityNormalisation





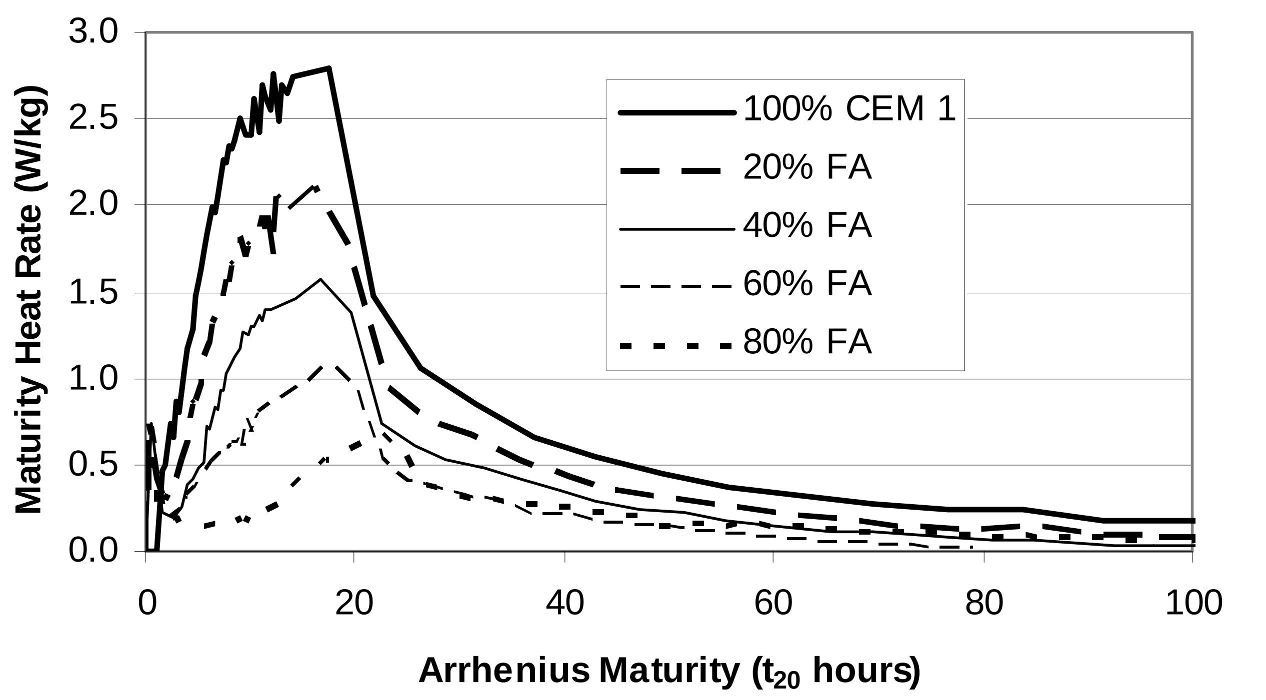

Clinker E
25 micron


Clinker K
25 micron

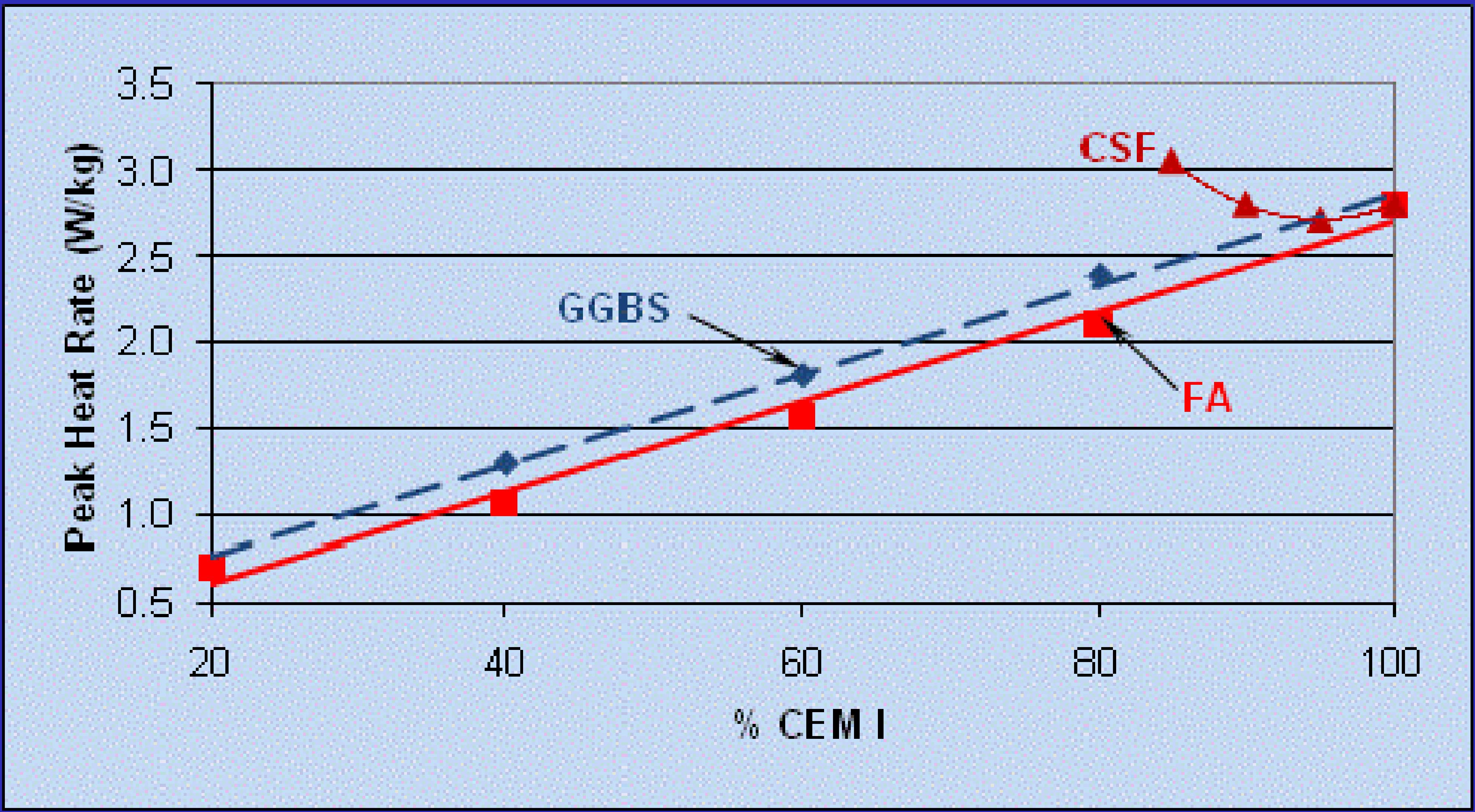


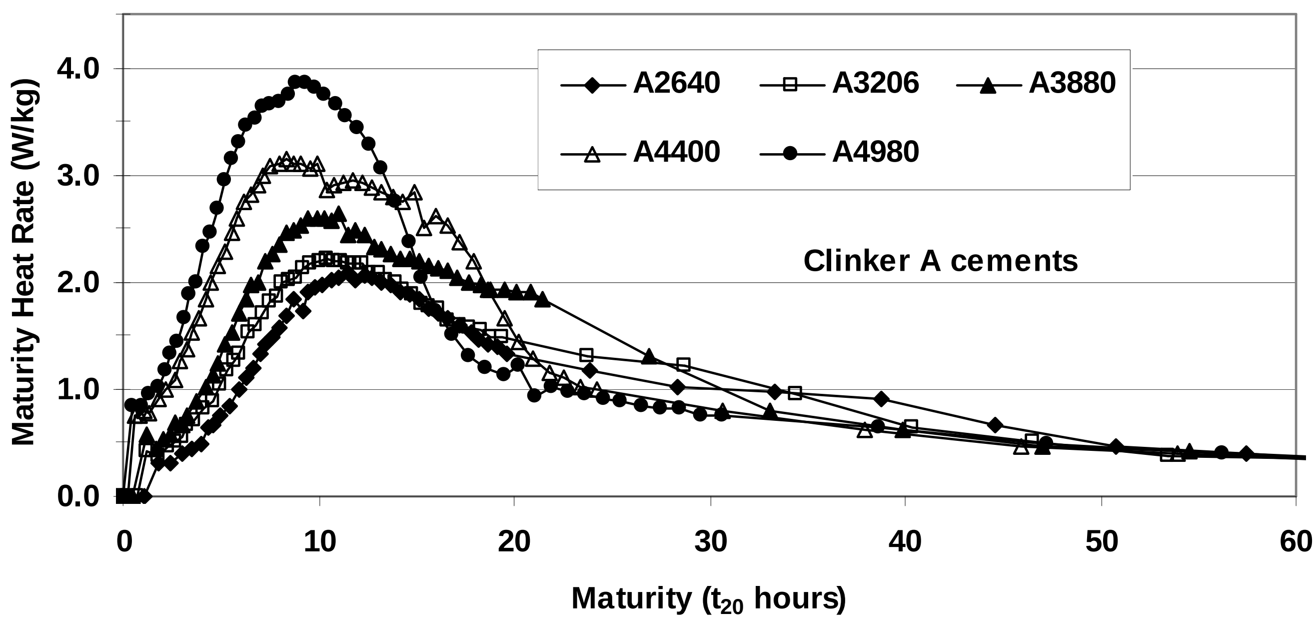
Material	Mass (g)
Binder	420
Stone	1020
Sand	1060
Water	280

Effect of cement extenders

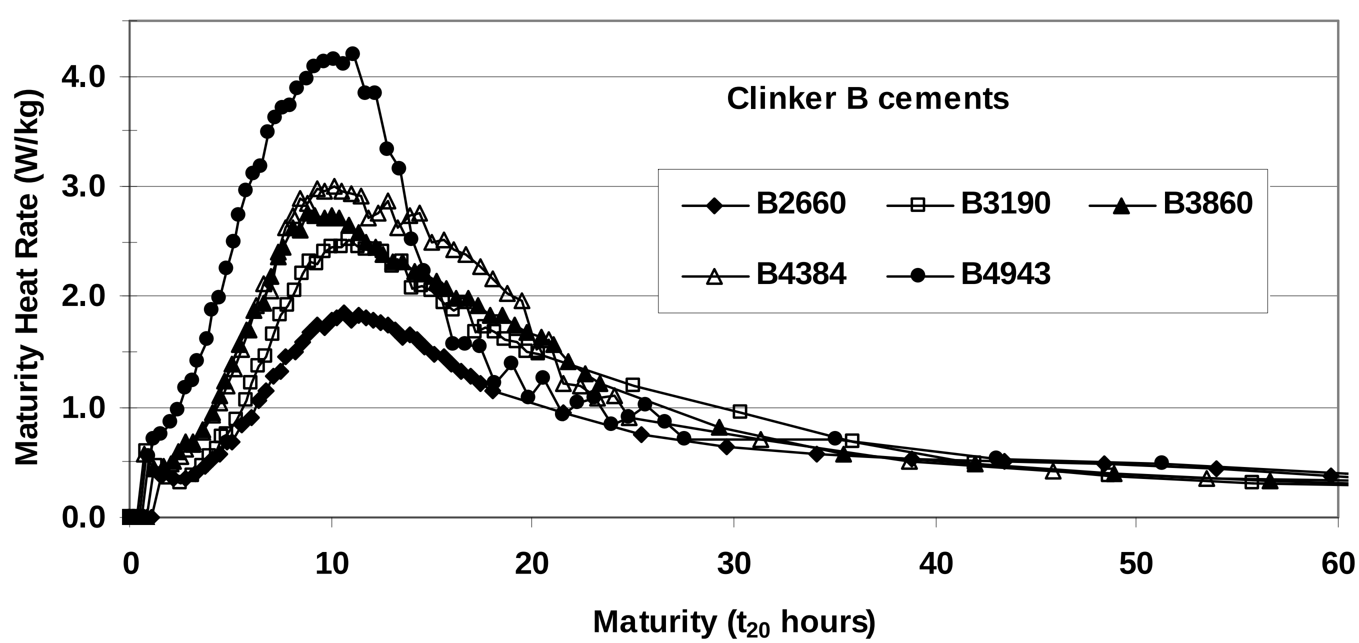


Effect on peak heat rate





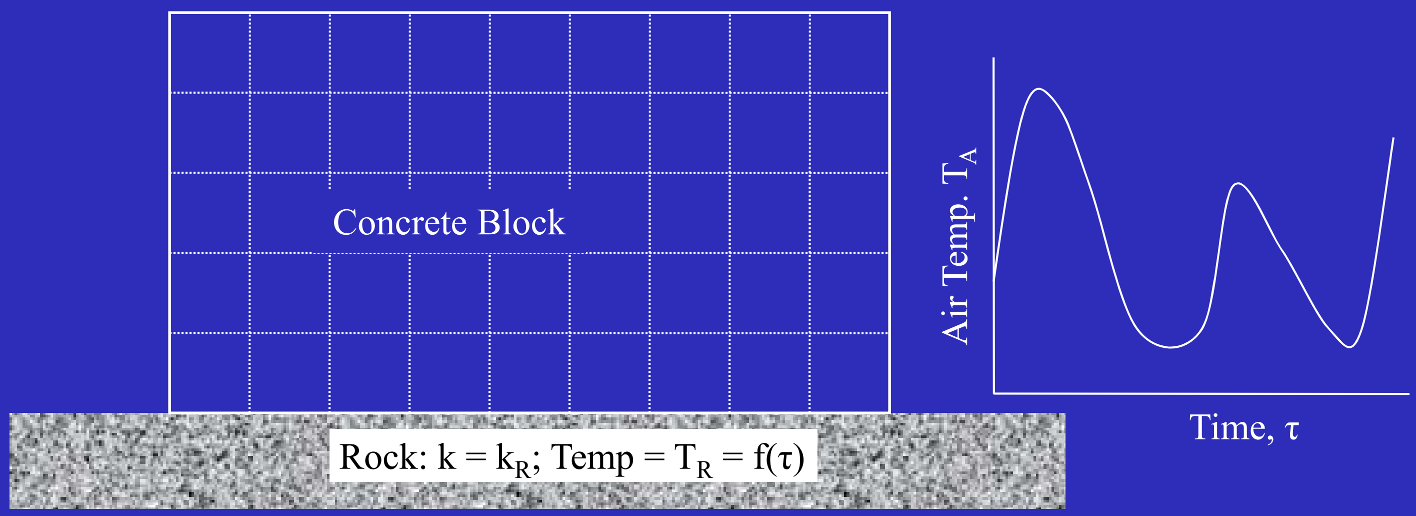
Effect of cement fineness



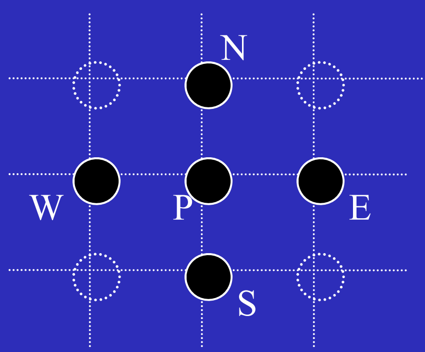
Modeling temperature development in mass concrete: The WITS University temperature prediction model

TEMPERATURE PREDICTION MODEL

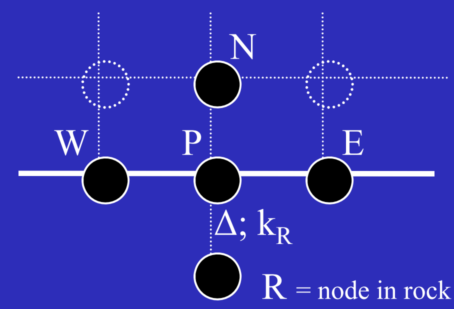
Element Modeled



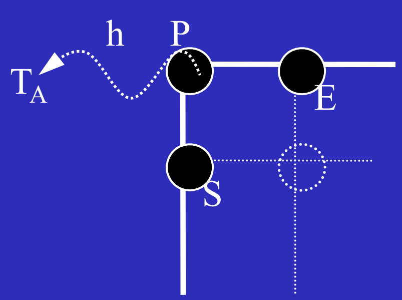
Finite Difference Analysis Nodes



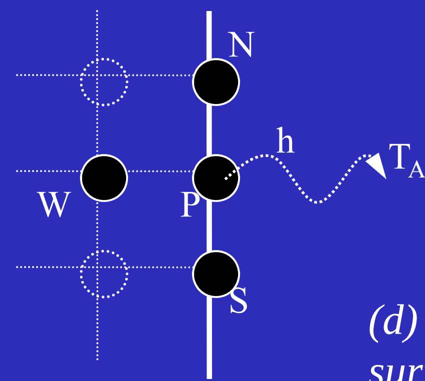
(a) P is an internal node



(b) P is a bottom node on rock



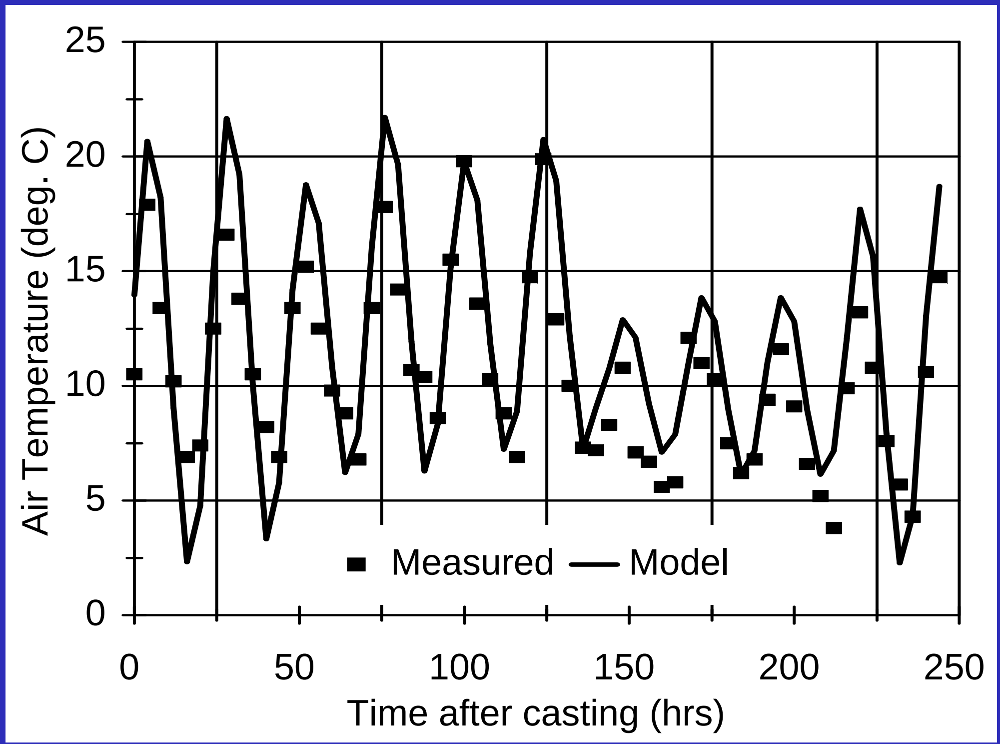
(c) P is a corner node



(d) P is an exposed surface node

Ambient Temperature Model

$$T_A = -\sin\left(\frac{2\pi(\tau_d + \tau_m)}{24}\right) \cdot \left(\frac{T_{\max} - T_{\min}}{2}\right) + \left(\frac{T_{\max} + T_{\min}}{2}\right)$$



Concrete profile modeled

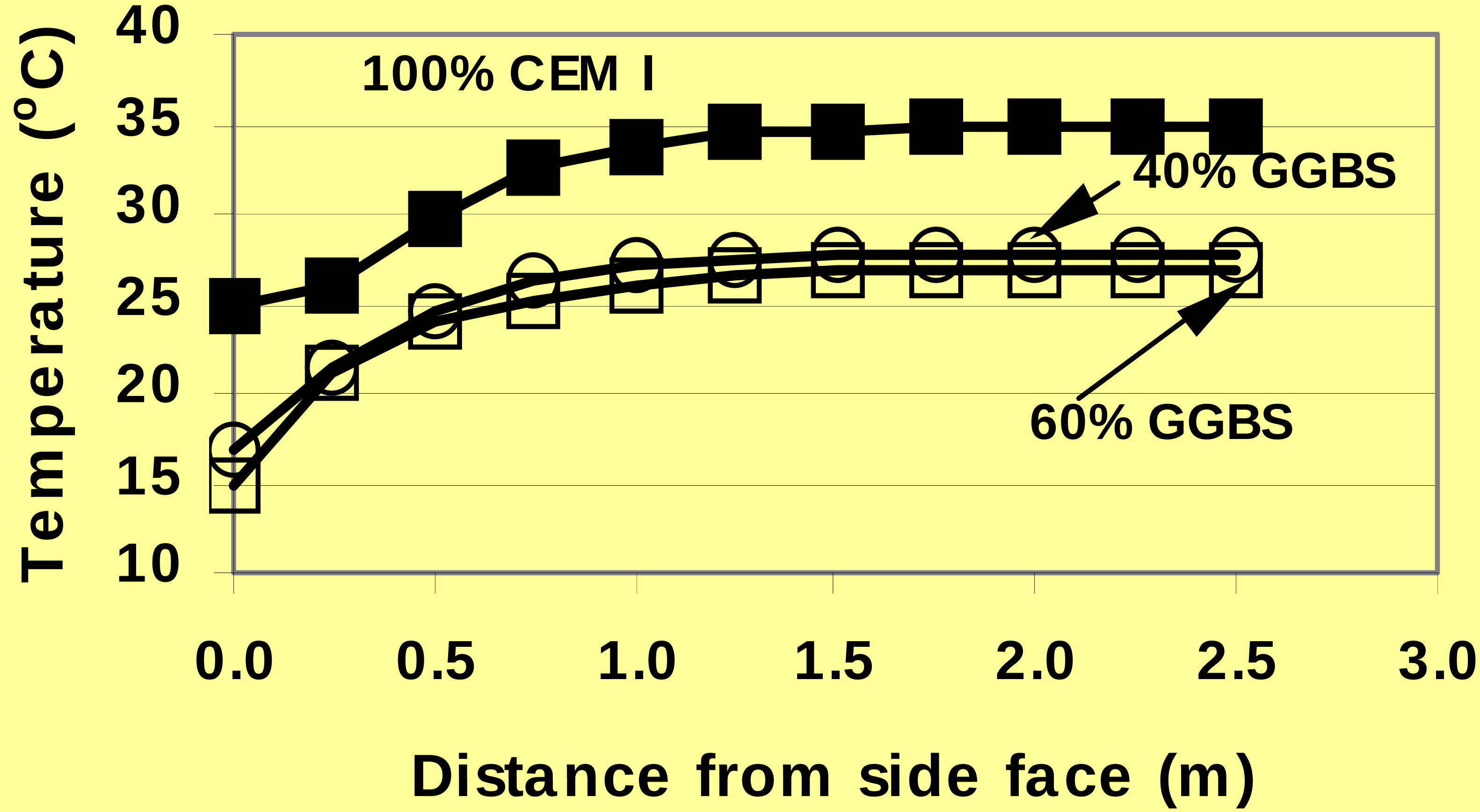
- k=2,7 W/m.K (Granite aggregate)
- C_p=1150 J/kg.K
- h=25 W/m^2.K for exposed surfaces
- h=5 W/m^2.K for surfaces with formwork (timber for the first 18 hours)
- Concrete cast at 10h00 at T_o=15 ^oC;
- Ambient temp between 12 ^oC and 25 ^oC.
- Finite difference $\Delta x = \Delta y = 250$ mm

Concrete element

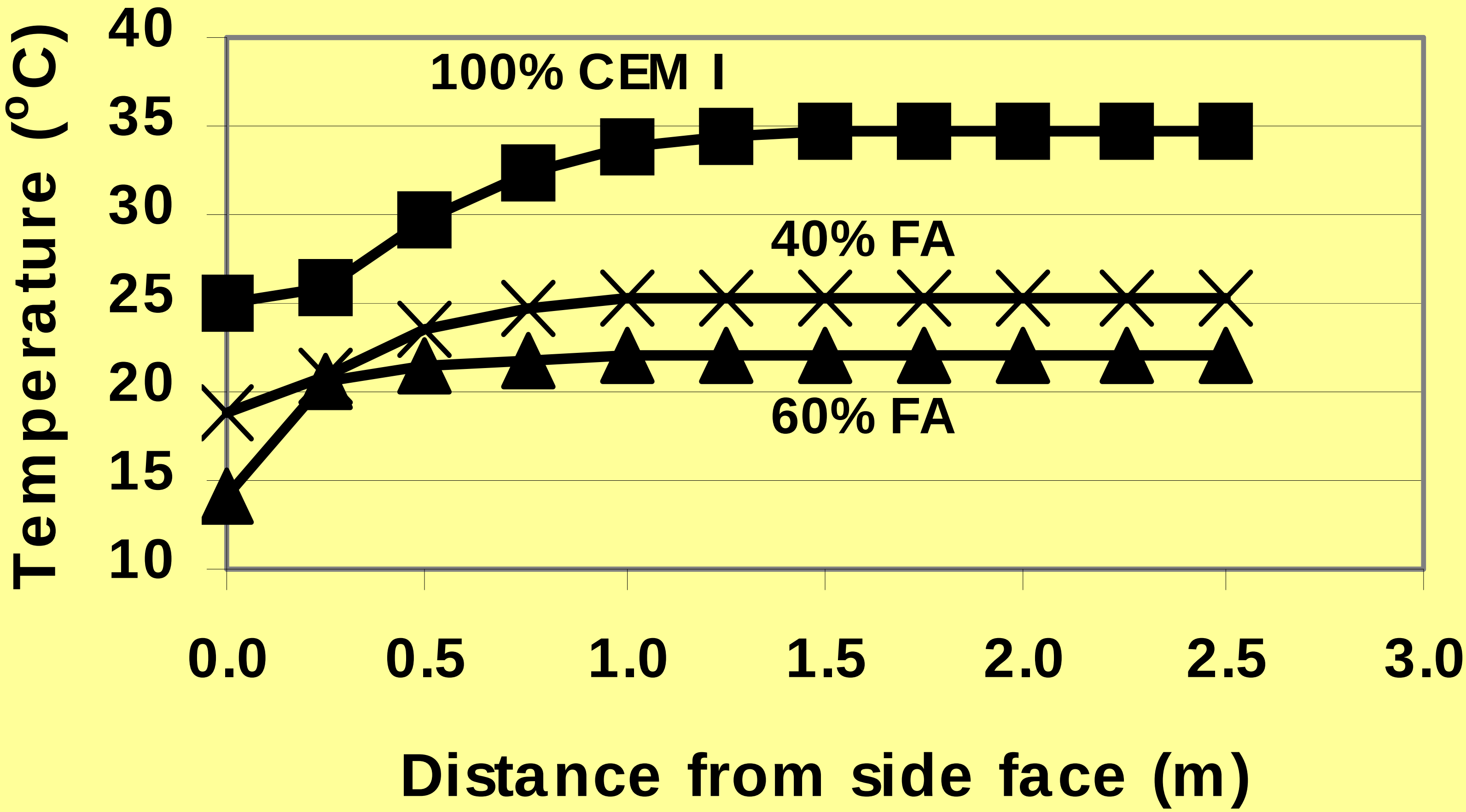
- Concrete = 5m wide x 2m high
- Concrete mixture details:

	Cem D	40% FA	60% FA	40% GGBS	60% GGBS
Binder	200	215	230	215	230
Water	160	160	160	160	160
Sand	600	500	500	585	570
Stone	1600	1680	1660	1600	1600

GGBS Concretes



Fly ash concretes



General Characteristics of Temperature Development

	Cem D	40% FA	60% FA	40% GGBS	60% GGBS
T_{Max} (^{o}C)	35	25	22	28	27
t_{Max} (t_{20} hrs)	80	72	64	94	116
ΔT_{Max} (^{o}C)	20	11	8	13	13
$t_{\Delta T}$(t_{20} hrs)	90	66	64	90	114

Caution: Late temperature development

Future Work

- Develop a physico-chemical model for the maturity-based heat rate function
- Incorporate extenders at a fundamental level
- Improved understanding and definition of boundary conditions in the model
- Allow for different structural configurations
- Develop a cracking model

THANK YOU

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