Portland Cement Con
arly Age using Embec
Temperature Sensors

ALICE CHAO

Graduate Student

RESEARCH

ONCRETE HYDRATION HEAT A

AM

TS

OF:

ON HEAT AND

ON ENERGY

RESEARCH

ONCRETE HYDRATION HEAT A

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TS

OF:

ON HEAT AND

ON ENERGY

king during hydration can le
vith quality concern, time co

e found on the investigation
ded fiber optic temperature

ALS,
NTS &
S

EXPERIMENTAL SET NO. 2
(JULY-SEPT 2011)

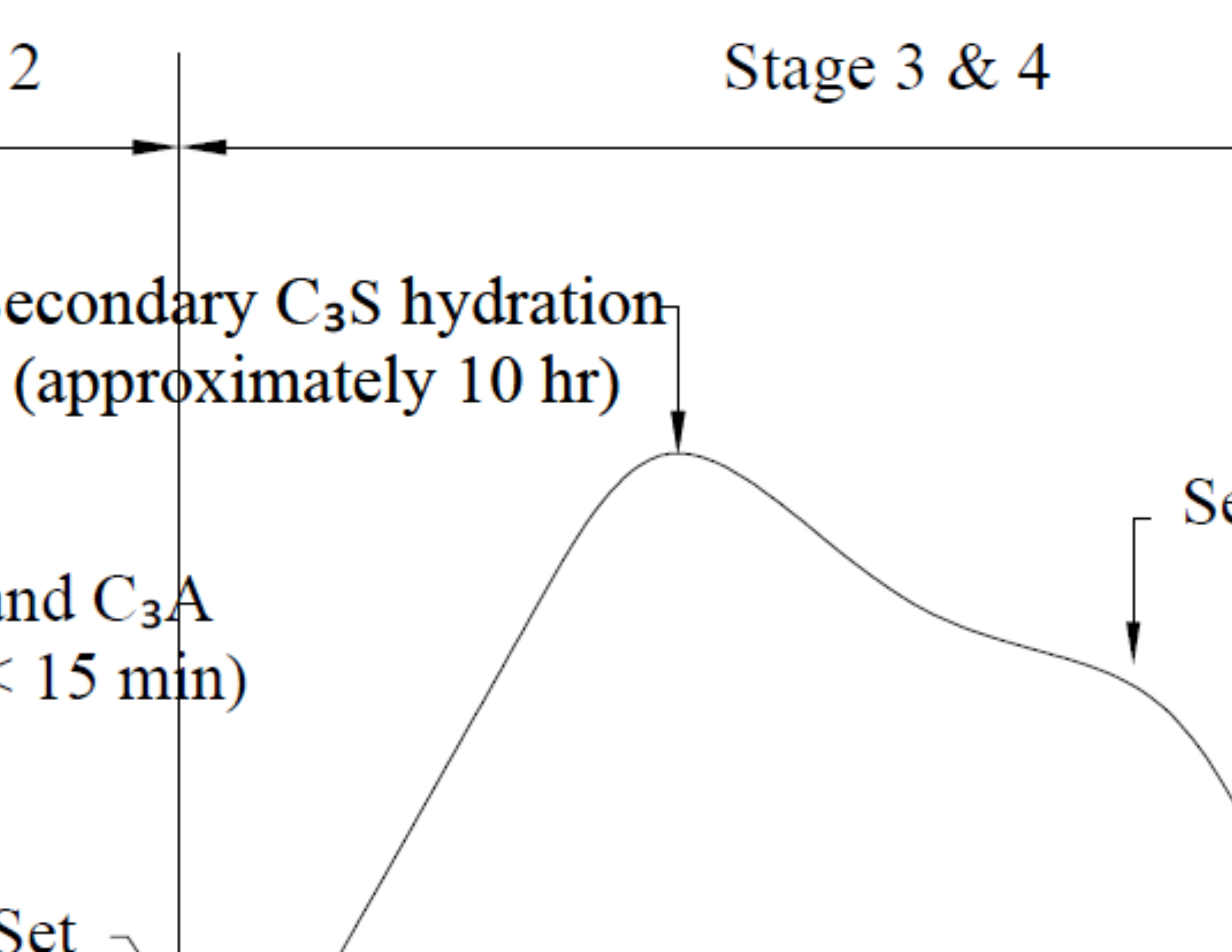
CONCRETE SPECIMENS

oduces the greatest rate of hea
ount of heat is developed with

mpounds that account for the l
lowest rates of reaction with w
$_2$S (dicalcium silicate) > C_3A
uminoferrite).

on and total heat liberated are r

f


2
Stage 3 & 4
C_3S hydration
(approximately 10 hr)
C_3A
15 min)
Set

nd reliability, more accurate, mu

ng in a range of structural materi

c sensors are fragile and therefor

ptic sensors used in civil enginee

of a single measurement point at

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OF:

ON HEAT AND

ON ENERGY

in, temperature and vibration simultane

periments under adiabatic conditions to
ement concrete.

emperature variation within concrete str
mocouple sensors.

rmed isothermal calorimetry test to stu
tion heat.

02) studied the impacts of high tempera

nidt methods.

buted FOS on to full-scale prestressed c

methods for calculating activation ener

tion, radiation and shading effects into

BG sensors in over 10 bridges in China

iew of FOSs used in I35W bridge in M

l to predict early age temperature profil

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ONCRETE HYDRATION HEAT A

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OF:

ON HEAT AND

ON ENERGY

ondition, using FP fiber optic temp

sor.

n the measured data, the amount o

were calculated using theoretical m

Dimension and w-c ratio used in ex

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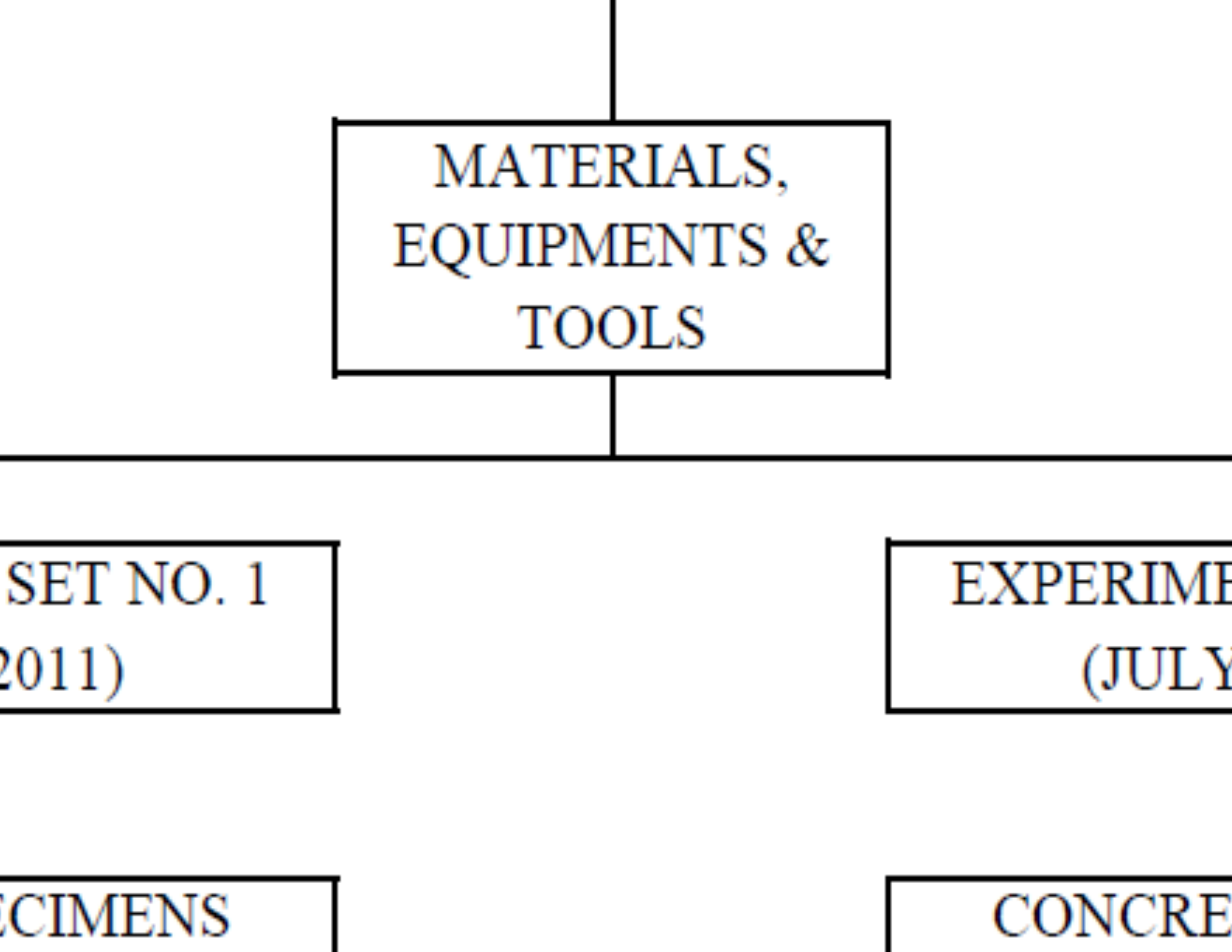
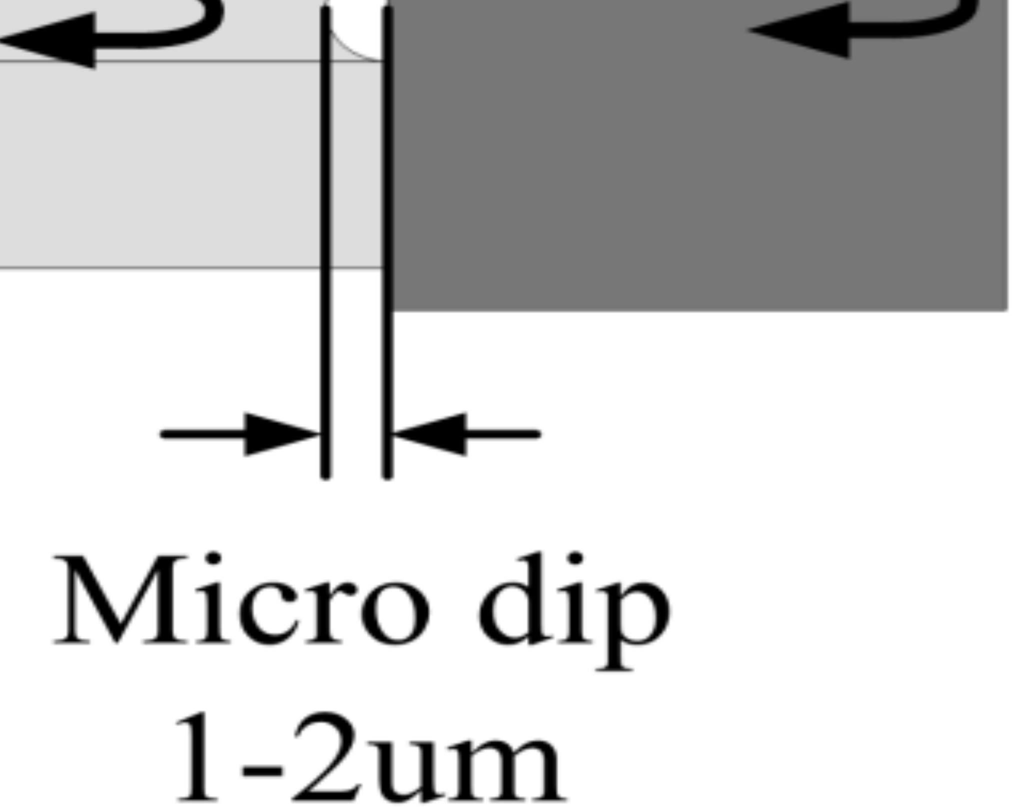
OF:

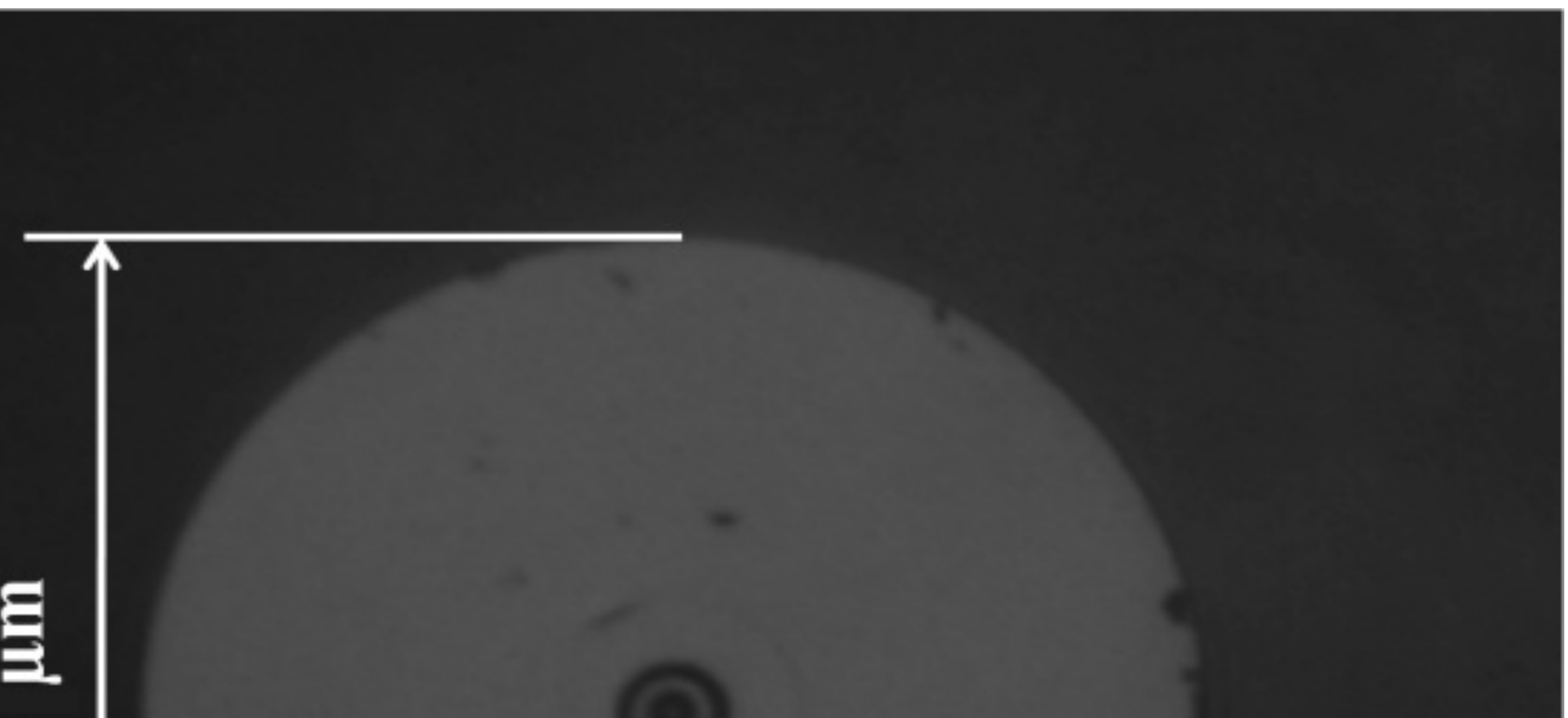
ON HEAT AND

ON ENERGY


MATERIALS, EQUIPMENTS & TOOLS
SET NO. 1
2011)
EXPERIME
(JULY
ECIMENS
CONCRE

8“ Specimens		3“ x	
r-cement-ratio		Wate	
0.50	0.60	0.4	0.45
1.510	1.510	0.637	0.637
2.562	2.562	1.081	1.081
3.719	3.719	1.569	1.569





expa
mode

Univ
Elec
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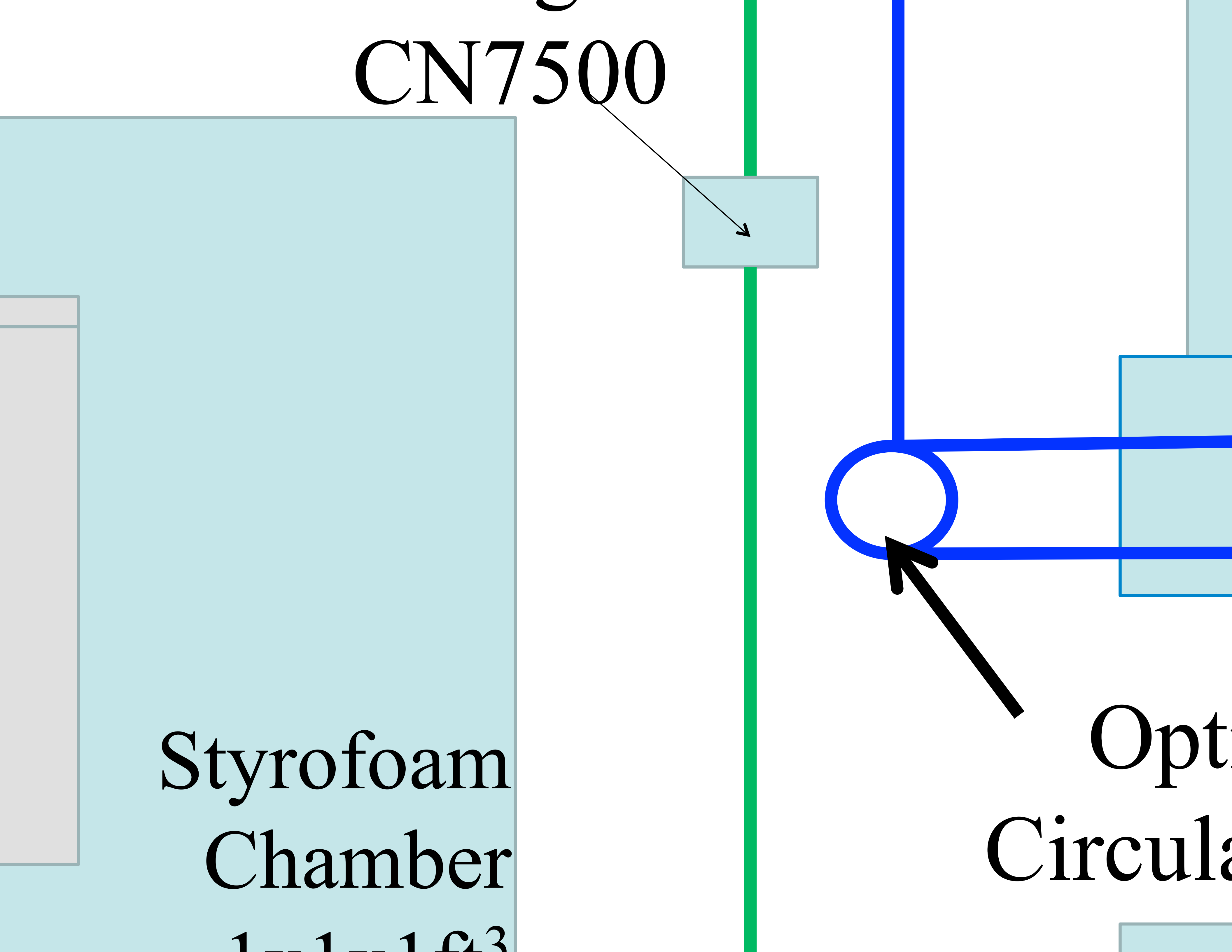
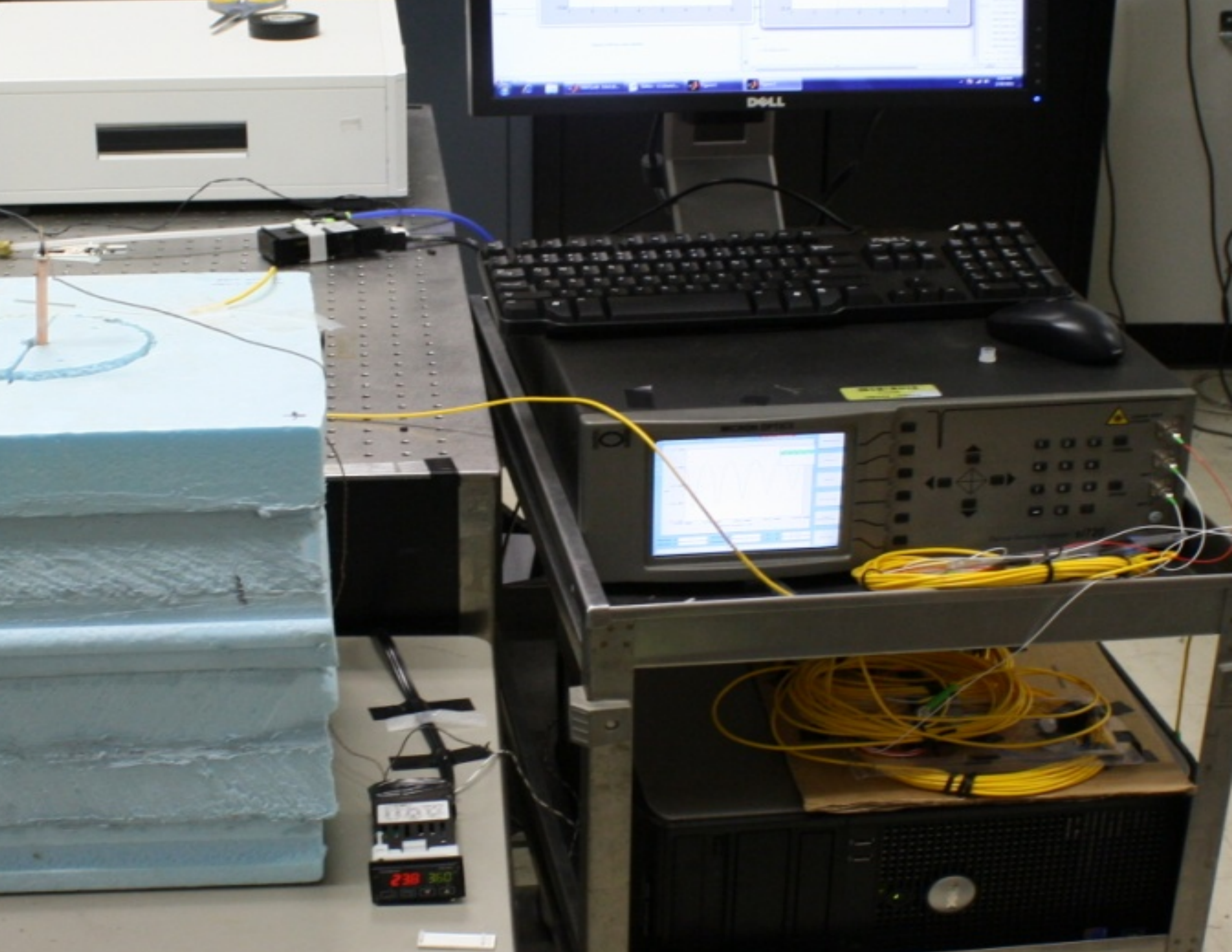
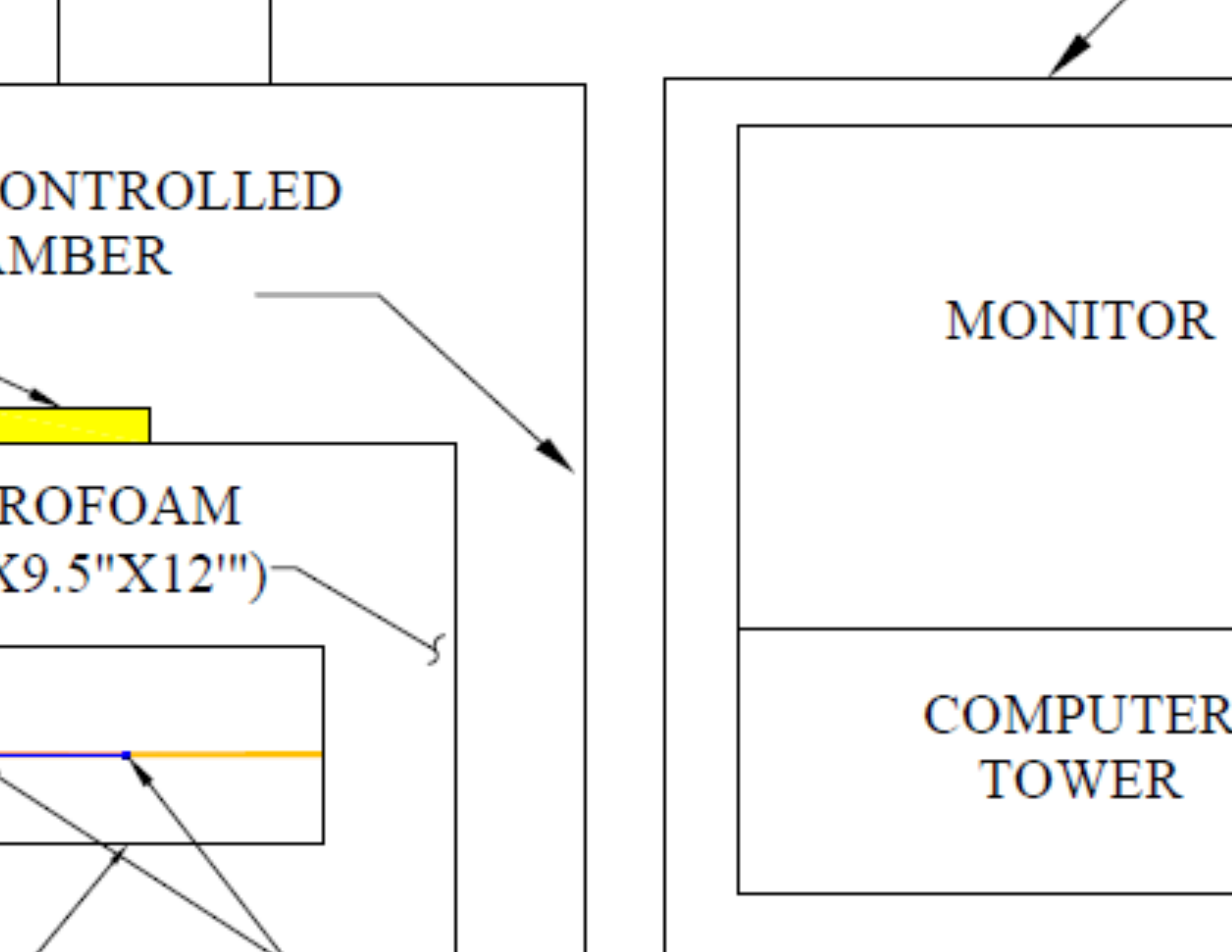
nt from the first experimental

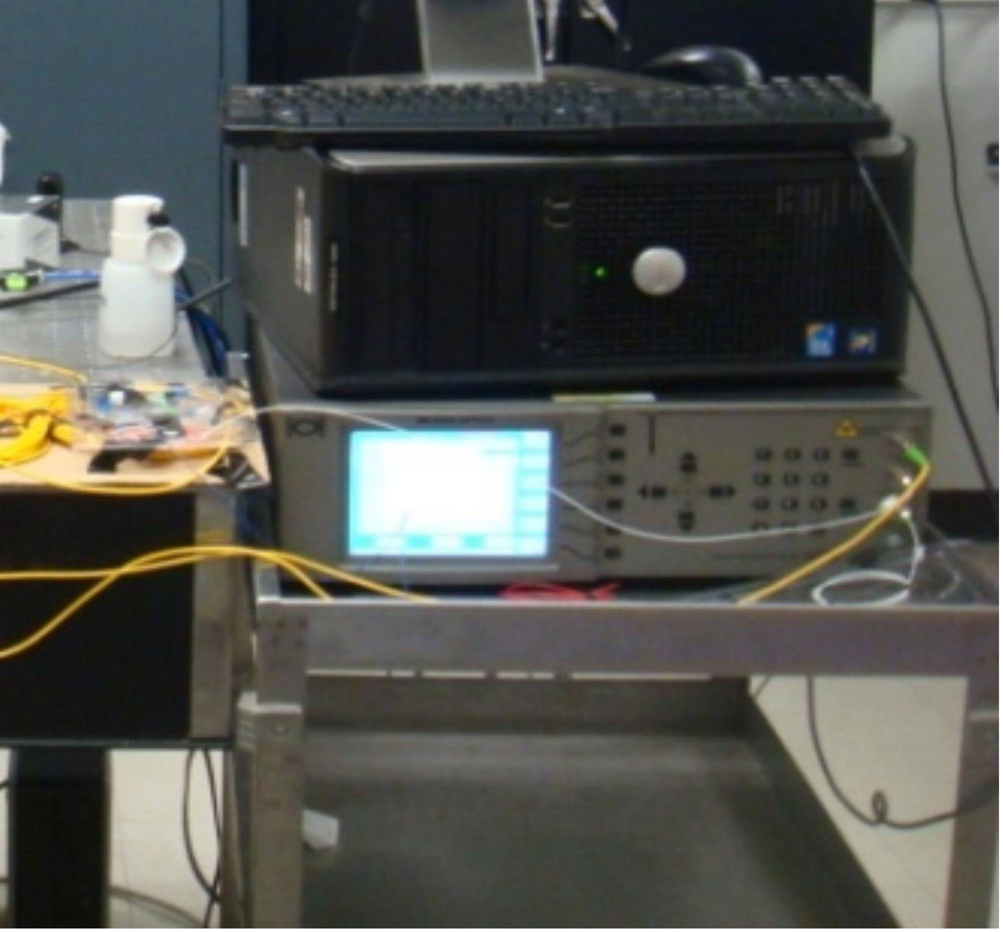
of surrounding conditions on
was found in the first experin
temperature changes when th
t value, which was 25 ºC in th
erature difference at the surfa

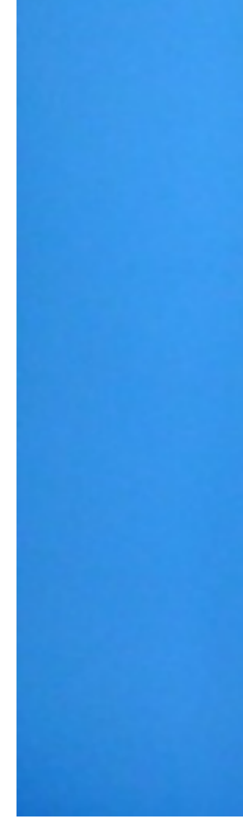

CN7500
Styrofoam
Chamber


DELL


ONTROLLED
AMBER
ROFOAM
X9.5"X12")
MONITOR
COMPUTER
TOWER


43



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ONCRETE HYDRATION HEAT A

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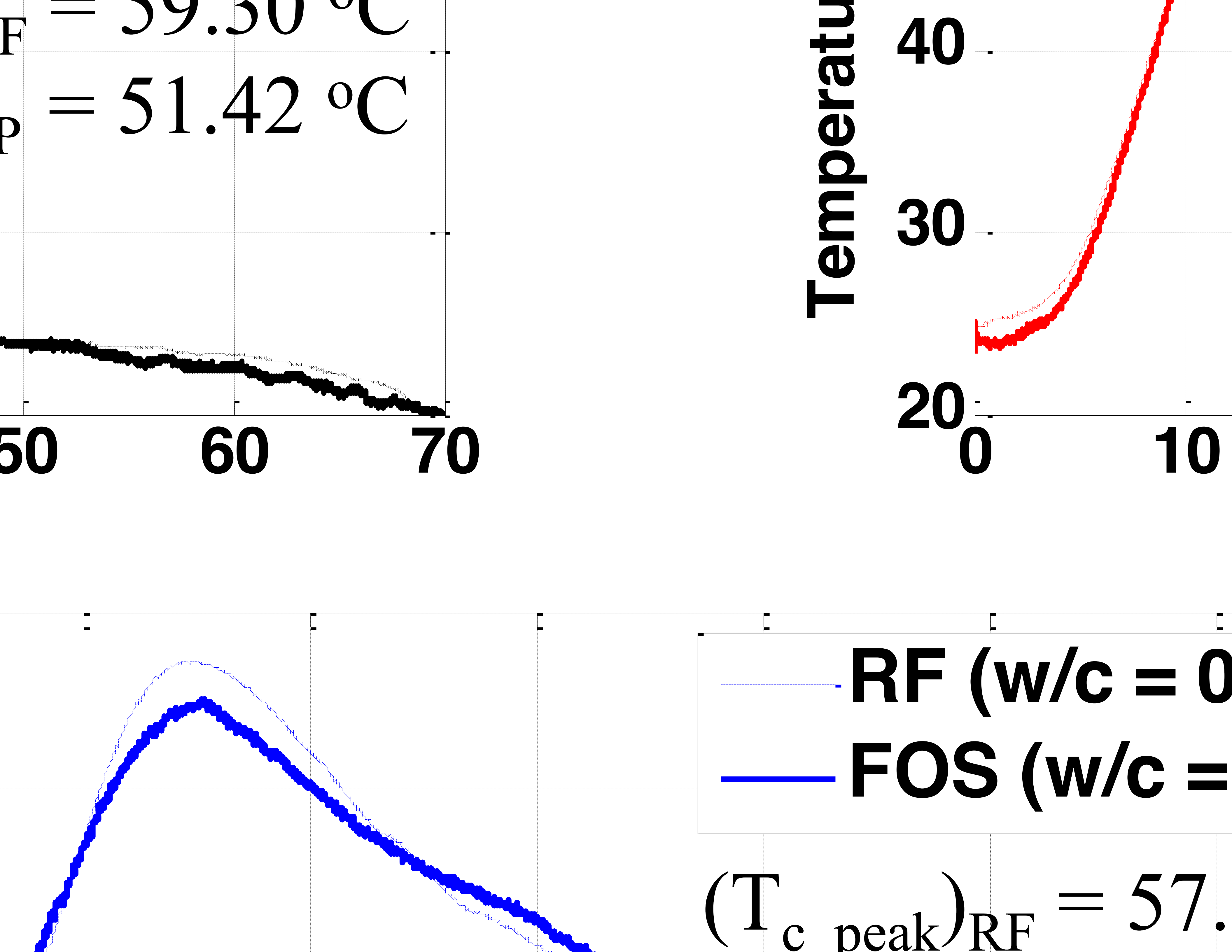
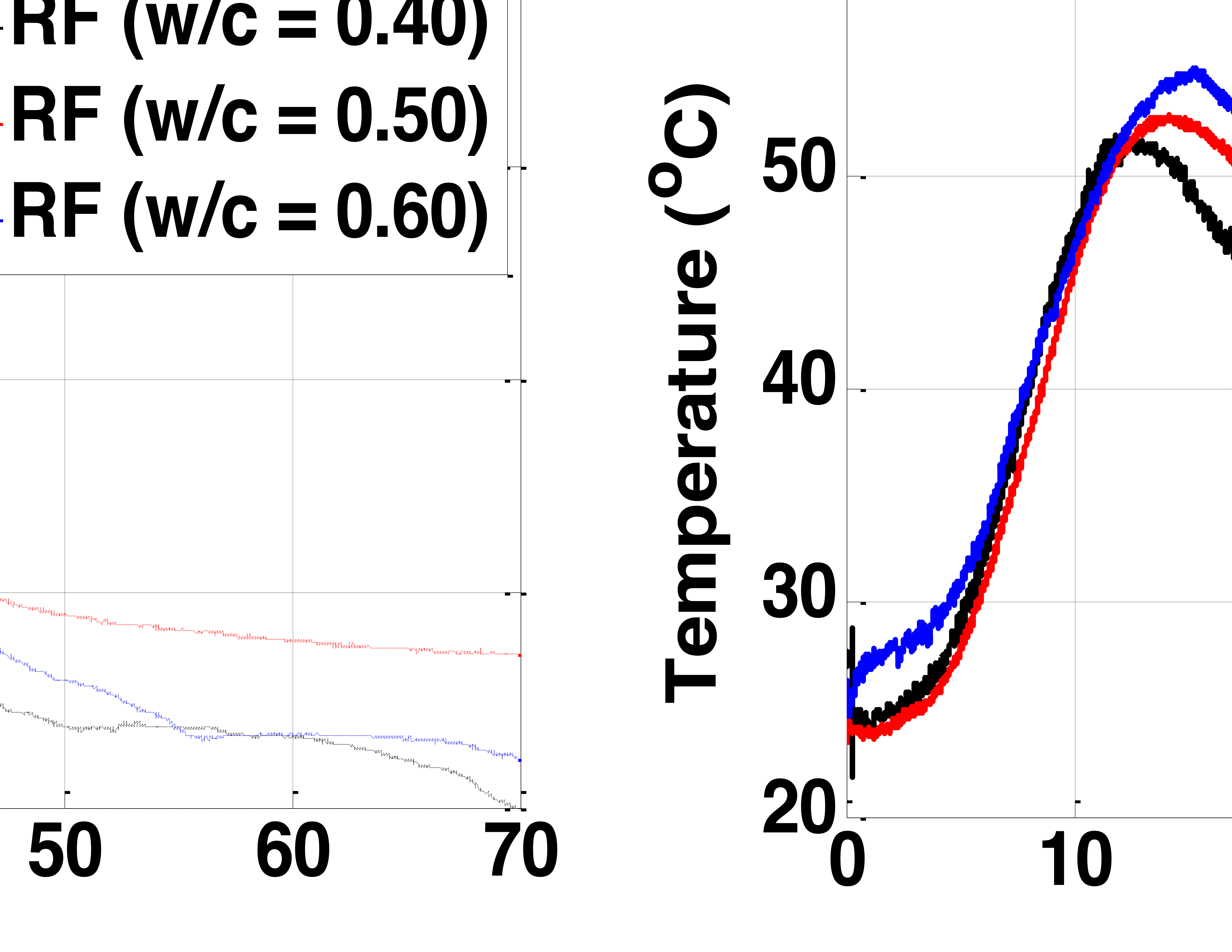
OF:

ON HEAT AND

ON ENERGY



= 59.30 °C
= 51.42 °C
50
60
70
Temperatu
40
30
20
0
10
RF (w/c = 0
FOS (w/c =
(Tc peak)RF = 57.

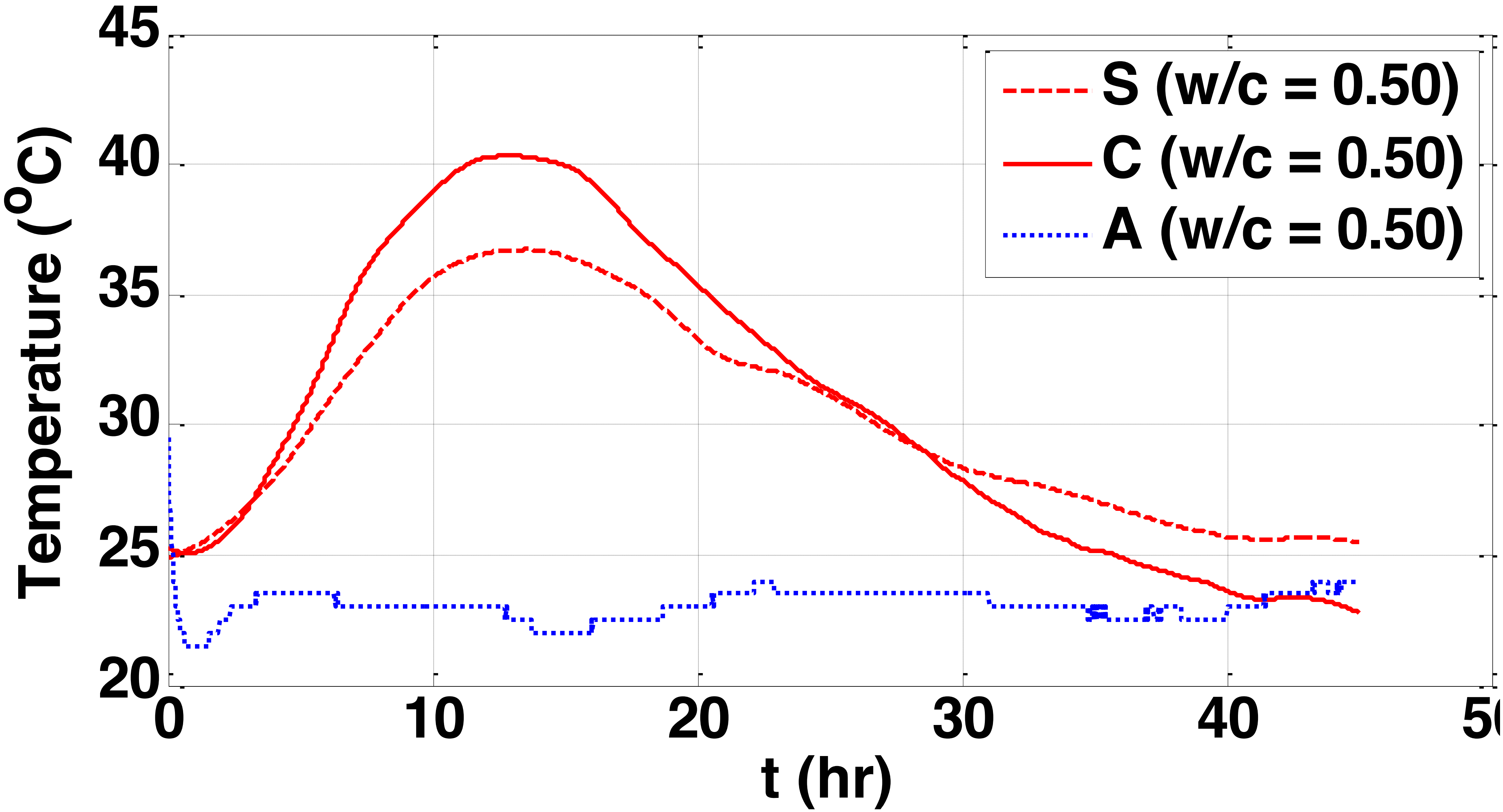


RF (w/c = 0.40)
RF (w/c = 0.50)
RF (w/c = 0.60)
50
60
70
Temperature (°C)
50
40
30
20
0
10

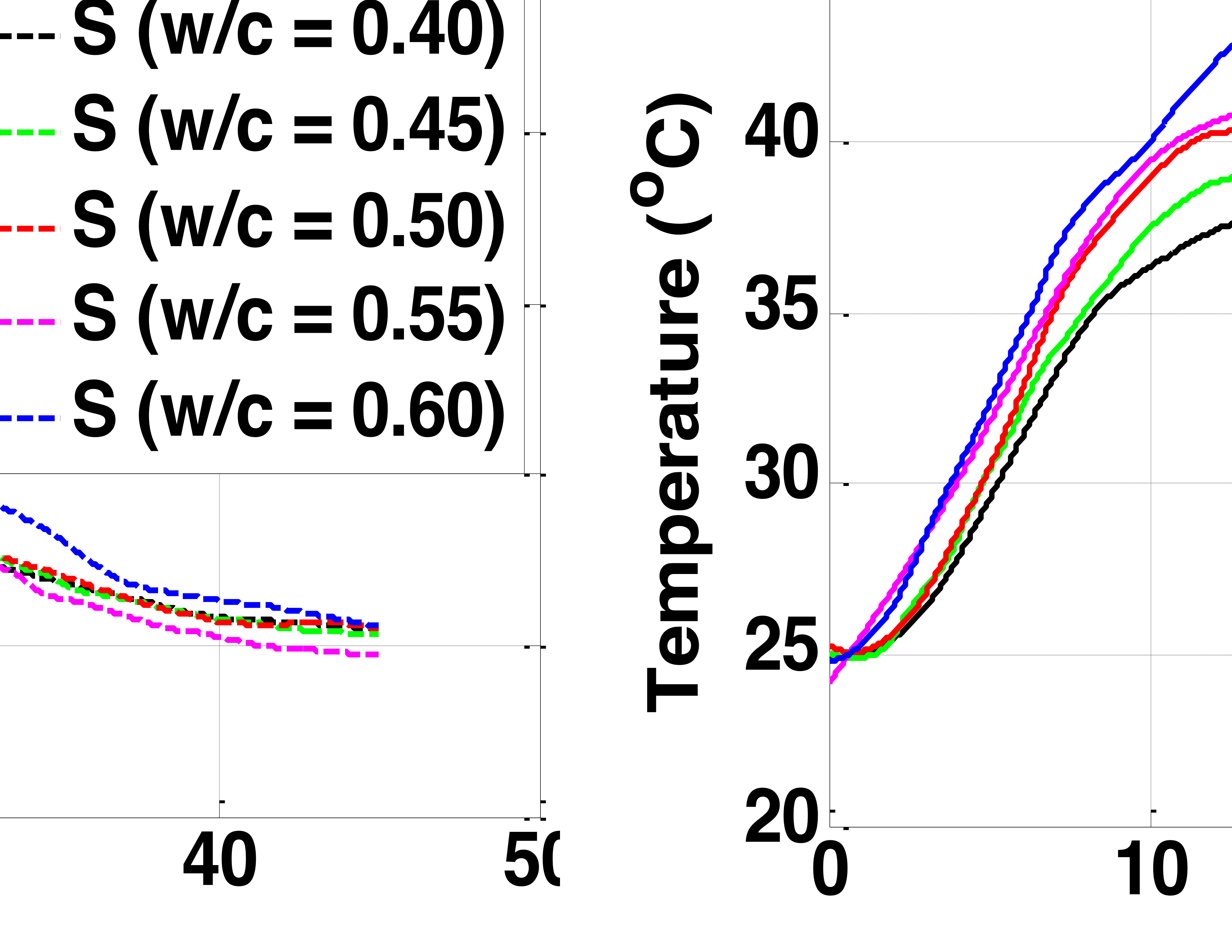
$(T_{c\_peak})_S$

$(T_{c\_peak})_C = 39.19$ °C

(w/c = 0.45



$(T_{c\_peak})_S = 36.74$ °C



S (w/c = 0.40)
S (w/c = 0.45)
S (w/c = 0.50)
S (w/c = 0.55)
S (w/c = 0.60)
40
50
Temperature (°C)
40
35
30
25
20
0
10

RESEARCH

ONCRETE HYDRATION HEAT A

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ON ENERGY

experimental sets.

- **1st Approach**: Used for c

  and heat of hydration

- **2nd Approach**: Used for

  E_{a1} and E_{a2} are 29000 J/

- Two values of E_a were se

  heat evolution within con

- **E_a = 29000 J/mol** was ch

commonly used in the pr

ity for hydrated products

terogeneous and compose

ons, the activation energy

rature at instant time (°K),

tion (DOH) at instant time (unit le

) = heat of hydration and H_u = ulti

$_{cem}$ x $P_{cem} + 461P_{slag} + 1800P_{FA-Ca}$

tion heat (kJ/kg)

ement over total cementitious conte

ag over total cementitious content,

hydration at time t (kJ/kg)

concrete specific heat (0.96kJ/kg/°

temperature (°C)

$$92 - 0.043T_c)(-0.00017 - C_p/H_u)$$

$$dH/dT_c = C_p$$

$^{46} \cdot P_{C3S}{}^{0.227} \cdot Blaine^{-0.535} \cdot P_{SO_3}{}^{0.558} \cdot e$

$v/cm)]/[0.194 + w/cm] + 0.5 \cdot P_{FA} +$

e parameter (hr)

pe parameter

ree of hydration

$/t_e)^{\beta} \times \alpha_u \times \exp(-\tau/t_e)^{\beta} \times \exp[E_a/$

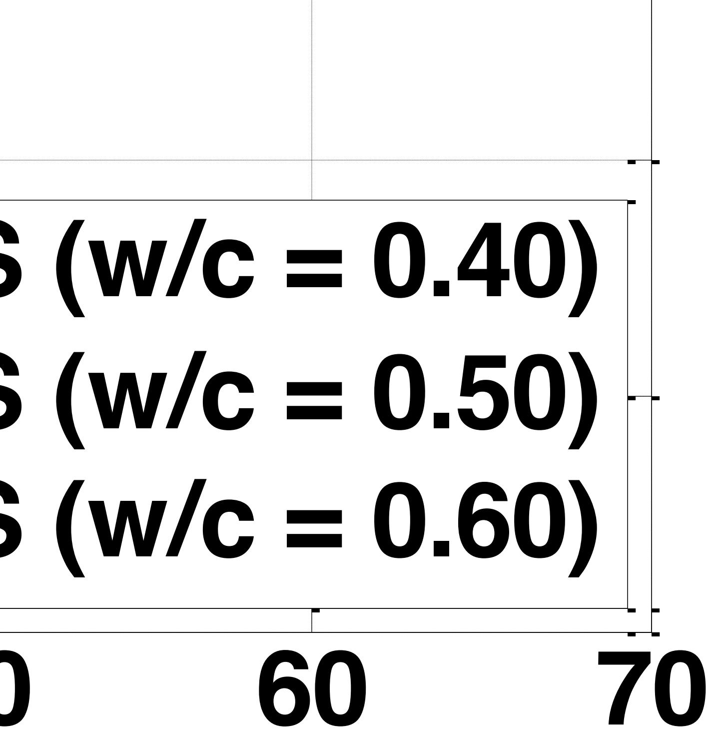
above

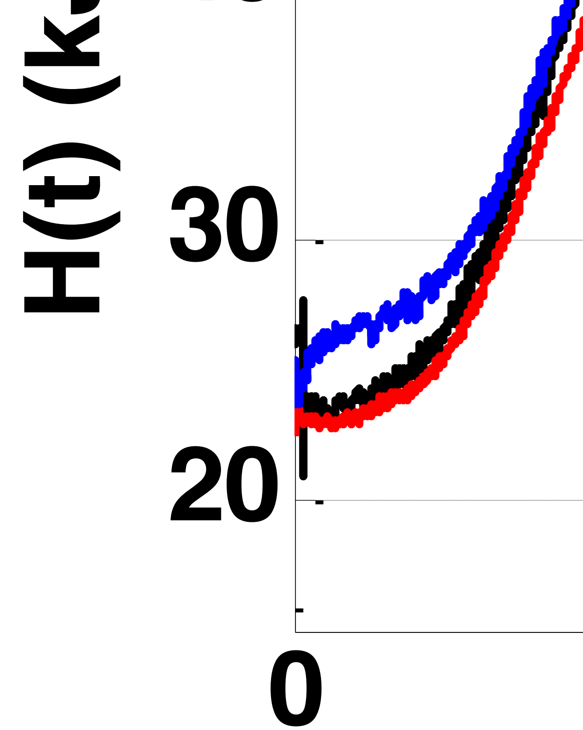
bove

nt activation energy (J/mol)

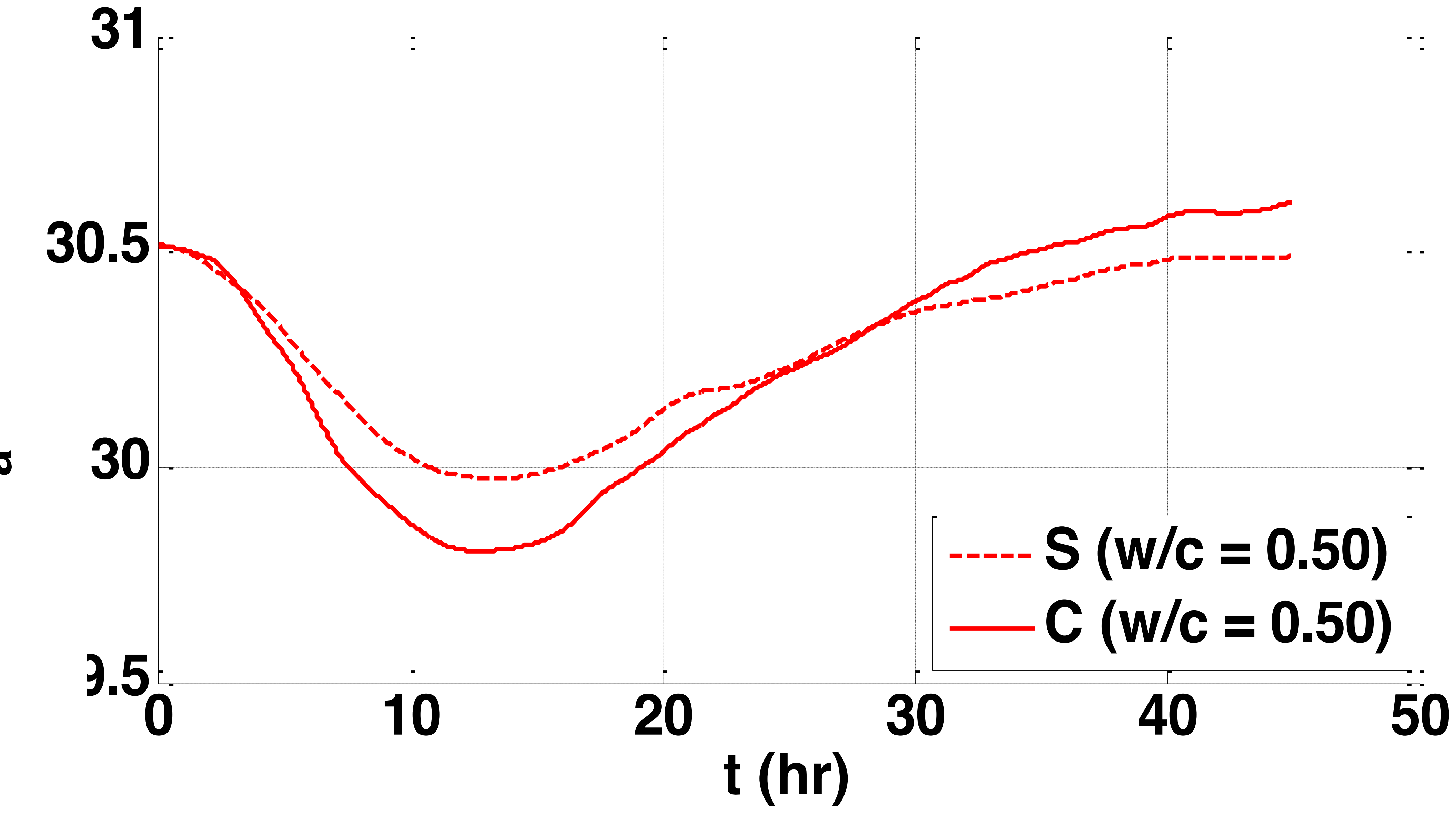
al gas constant (8.3144J/mol/^{o}

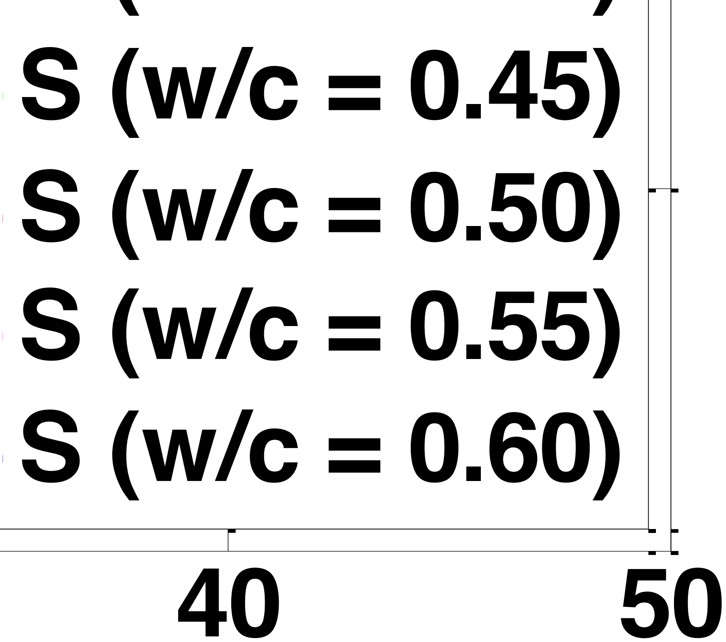
P(t), concrete hydration heat

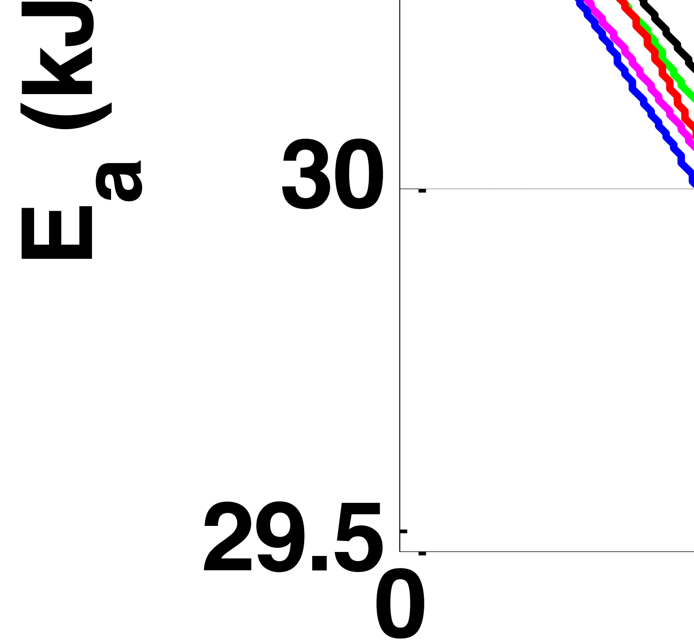




ergy of
s w/c

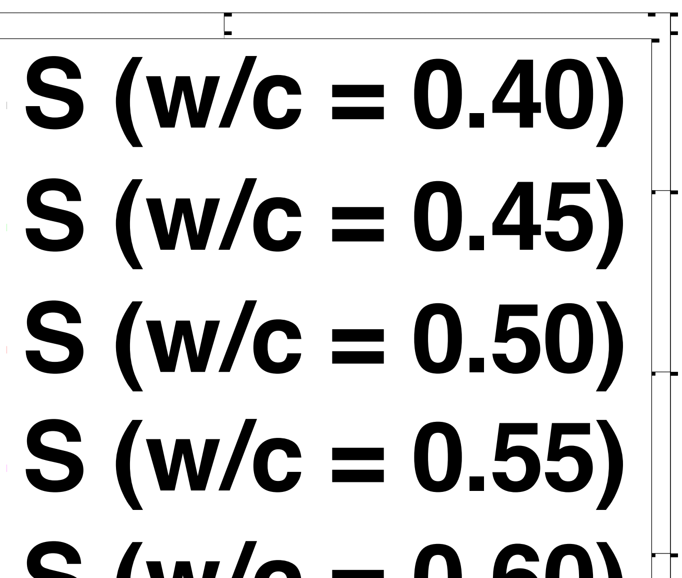

31
30.5
30
9.5
0
10
20
30
40
50
t (hr)
S (w/c = 0.50)
C (w/c = 0.50)

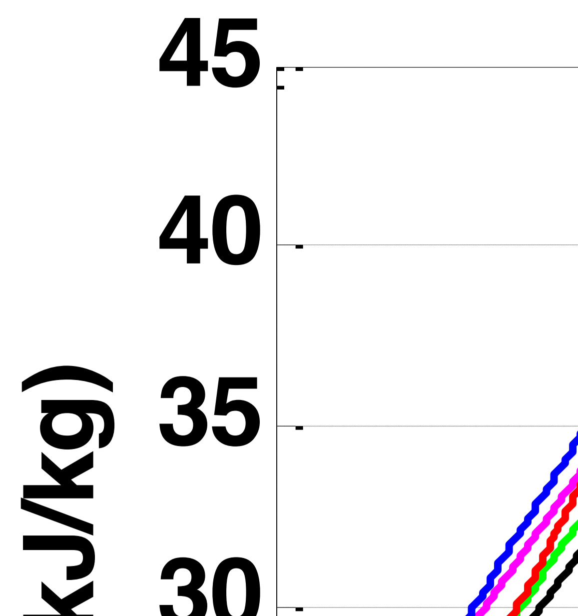


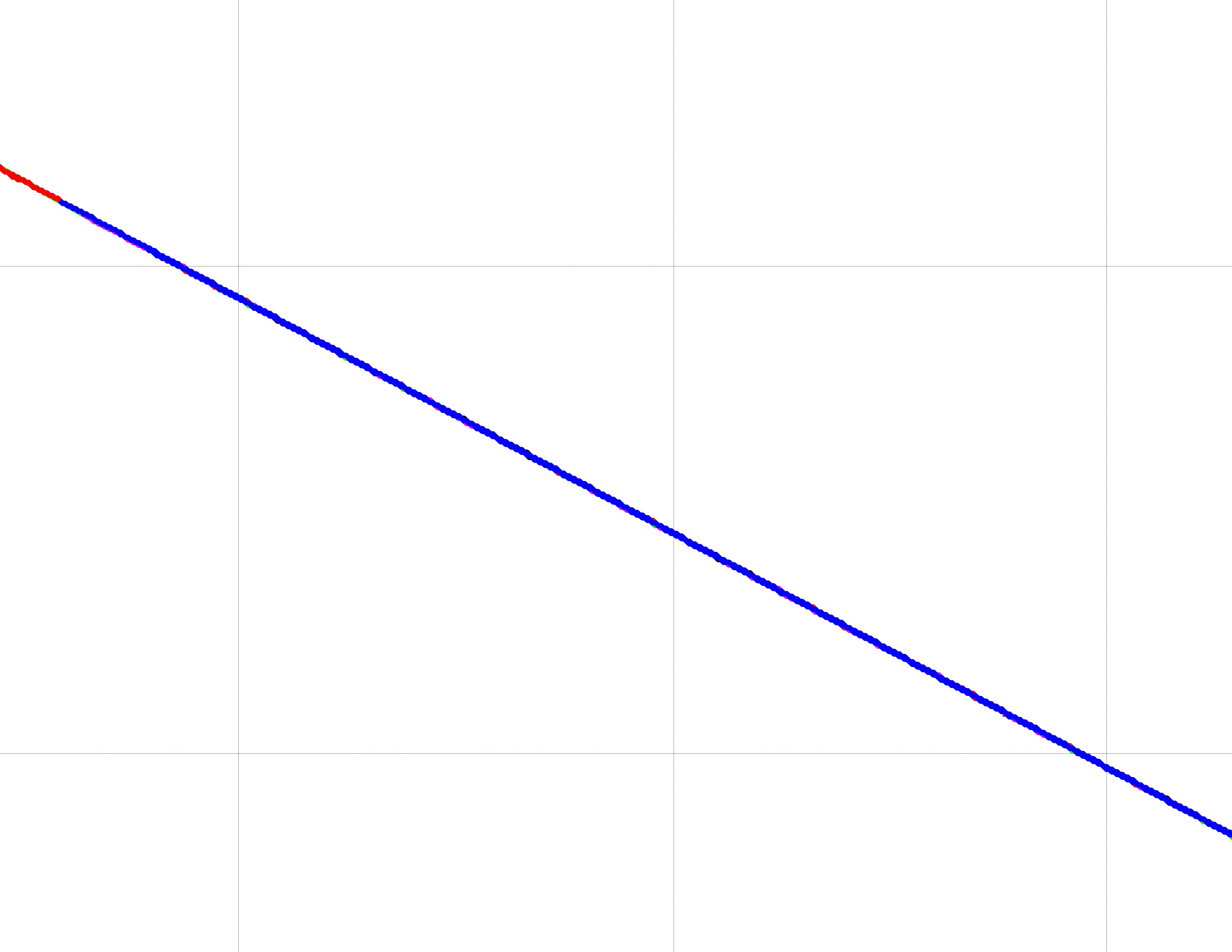


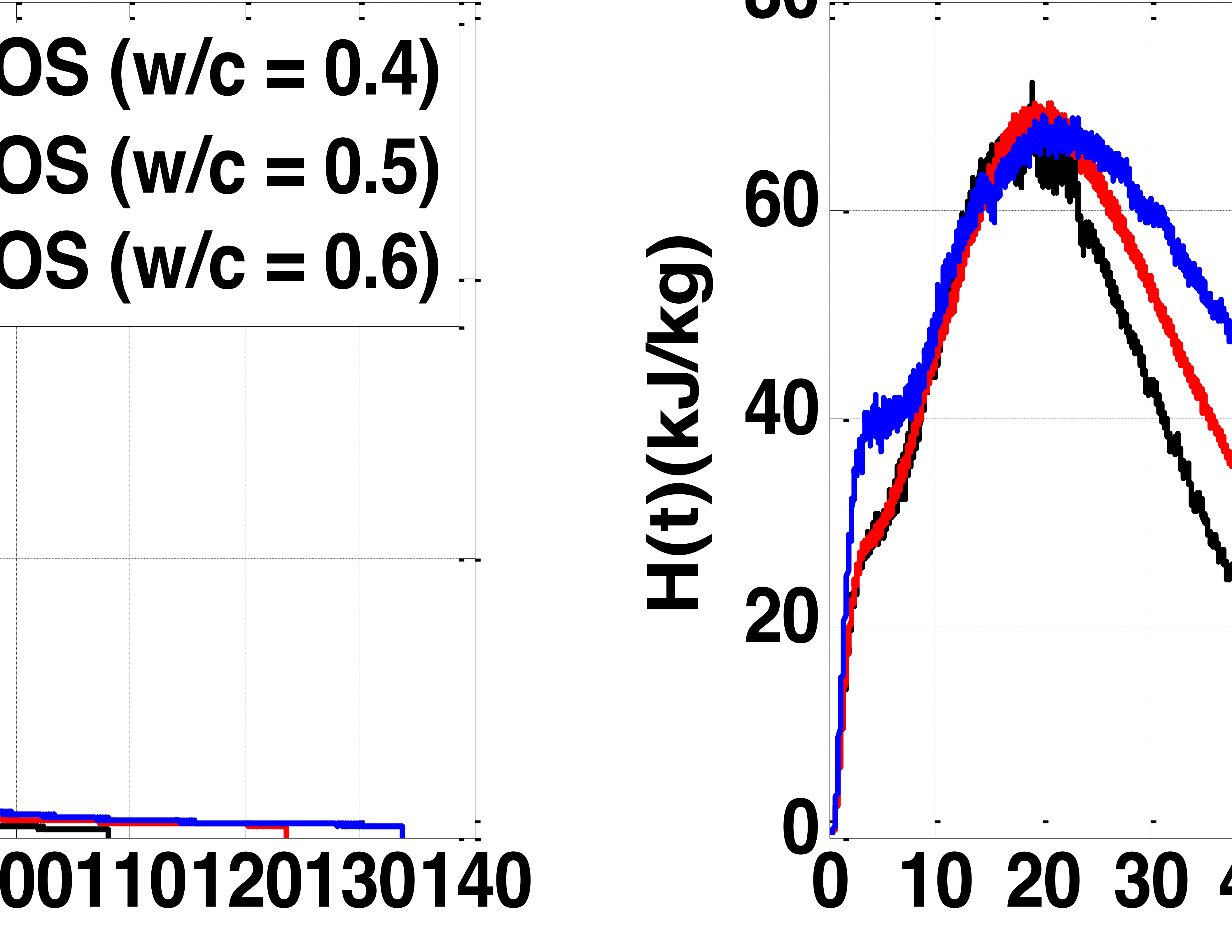
n energy at
ious w/c

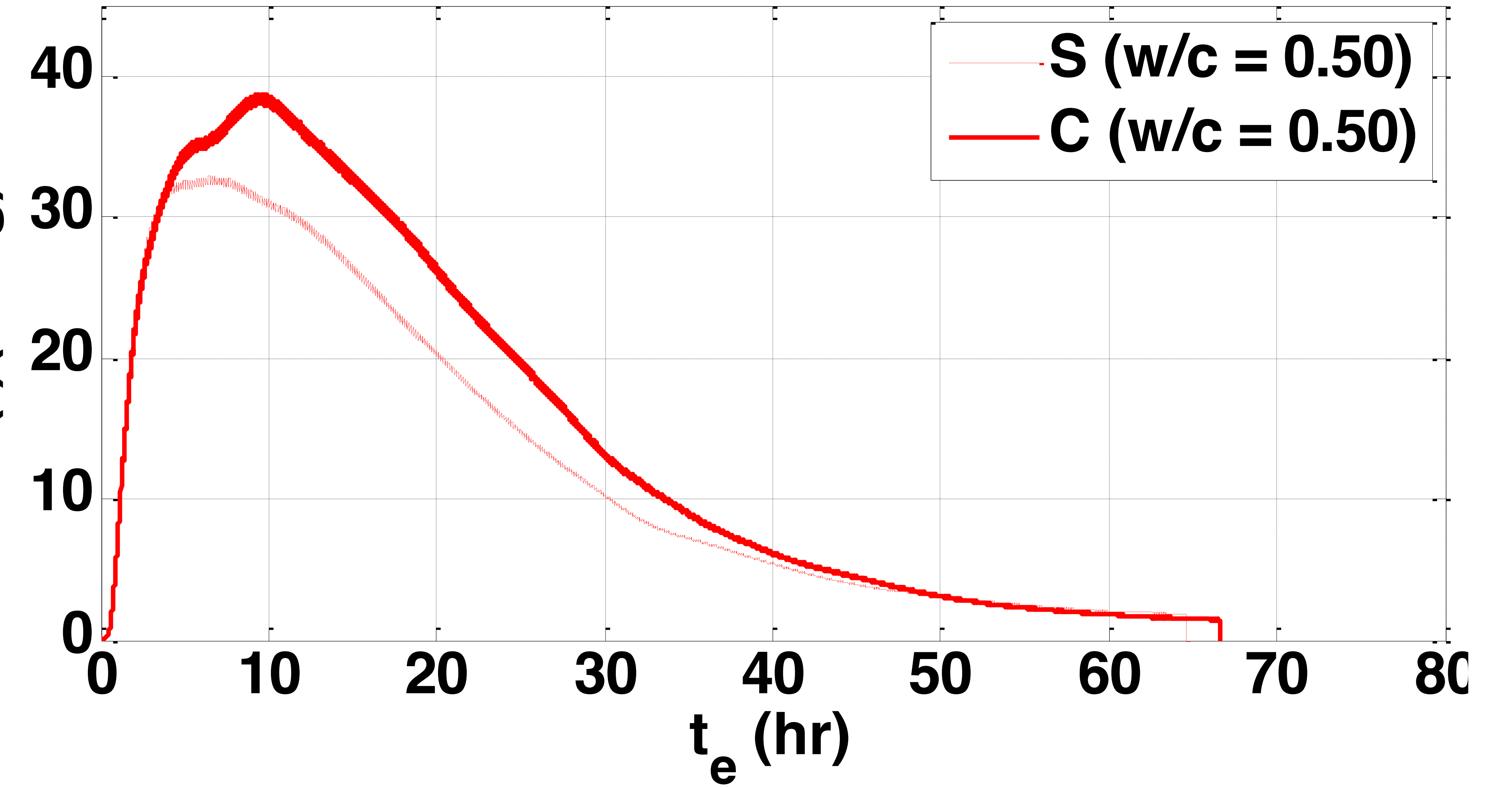
Figure



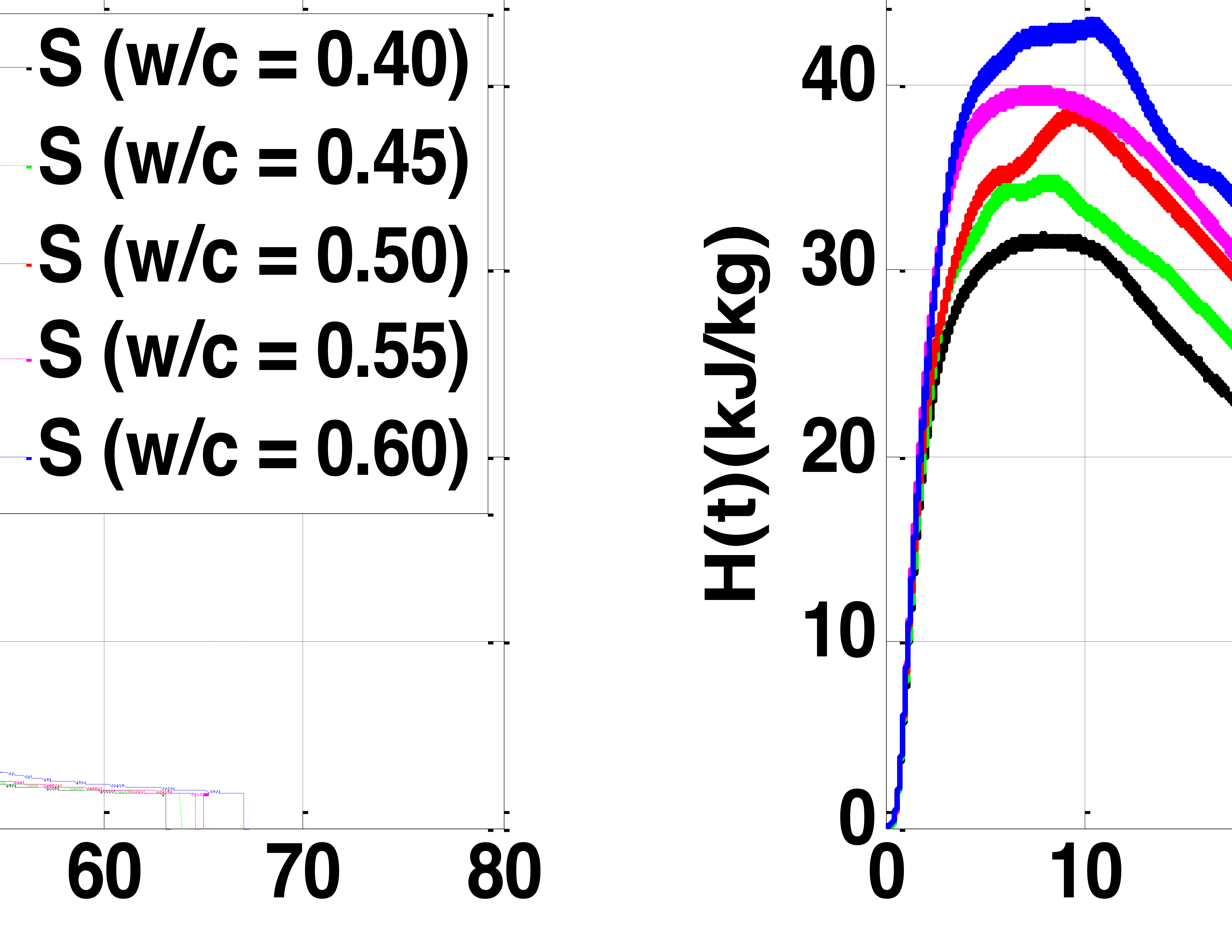




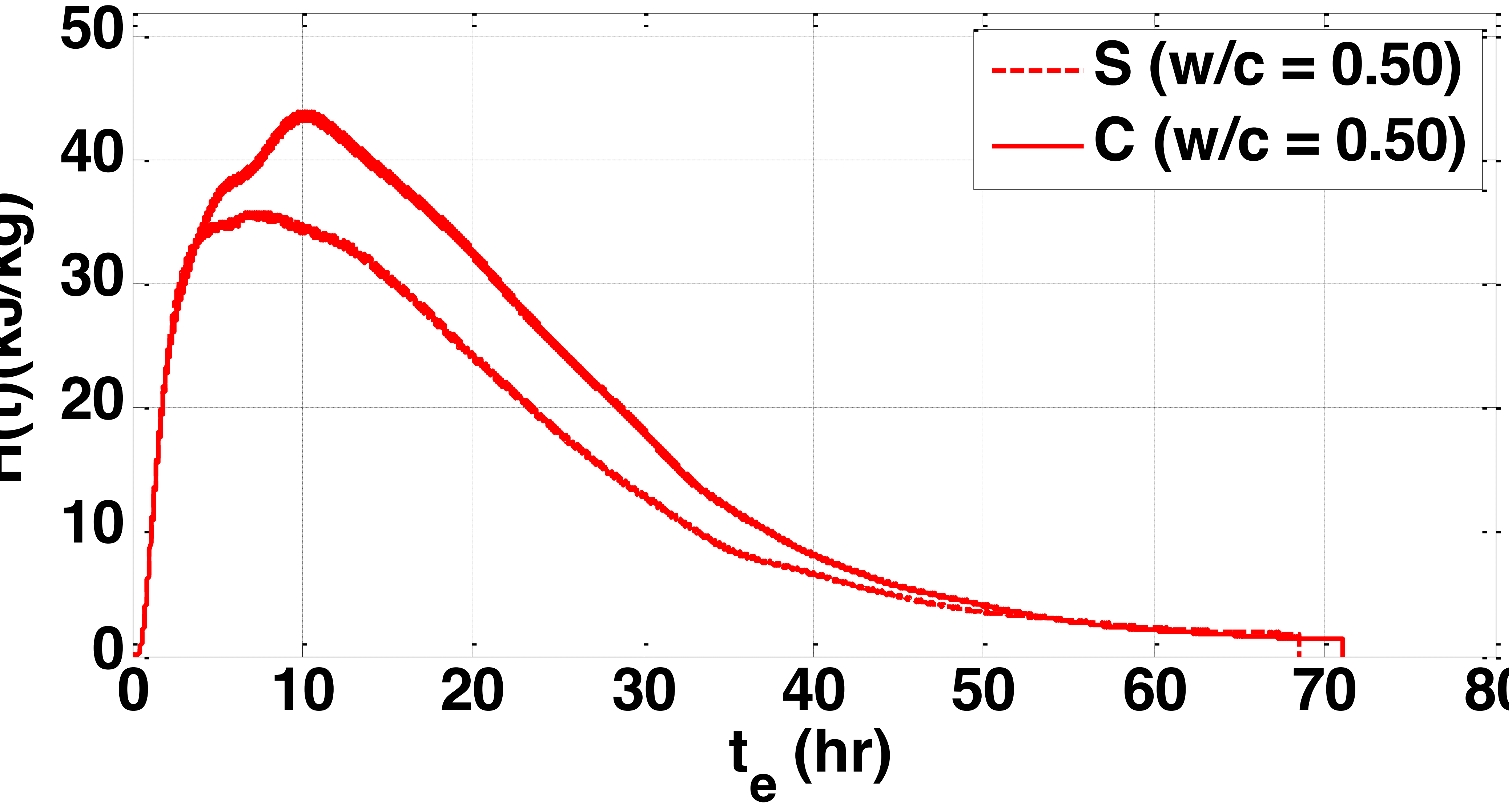

OS (w/c = 0.4)
OS (w/c = 0.5)
OS (w/c = 0.6)
00110120130140
H(t)(kJ/kg)
60
40
20
0
0 10 20 30



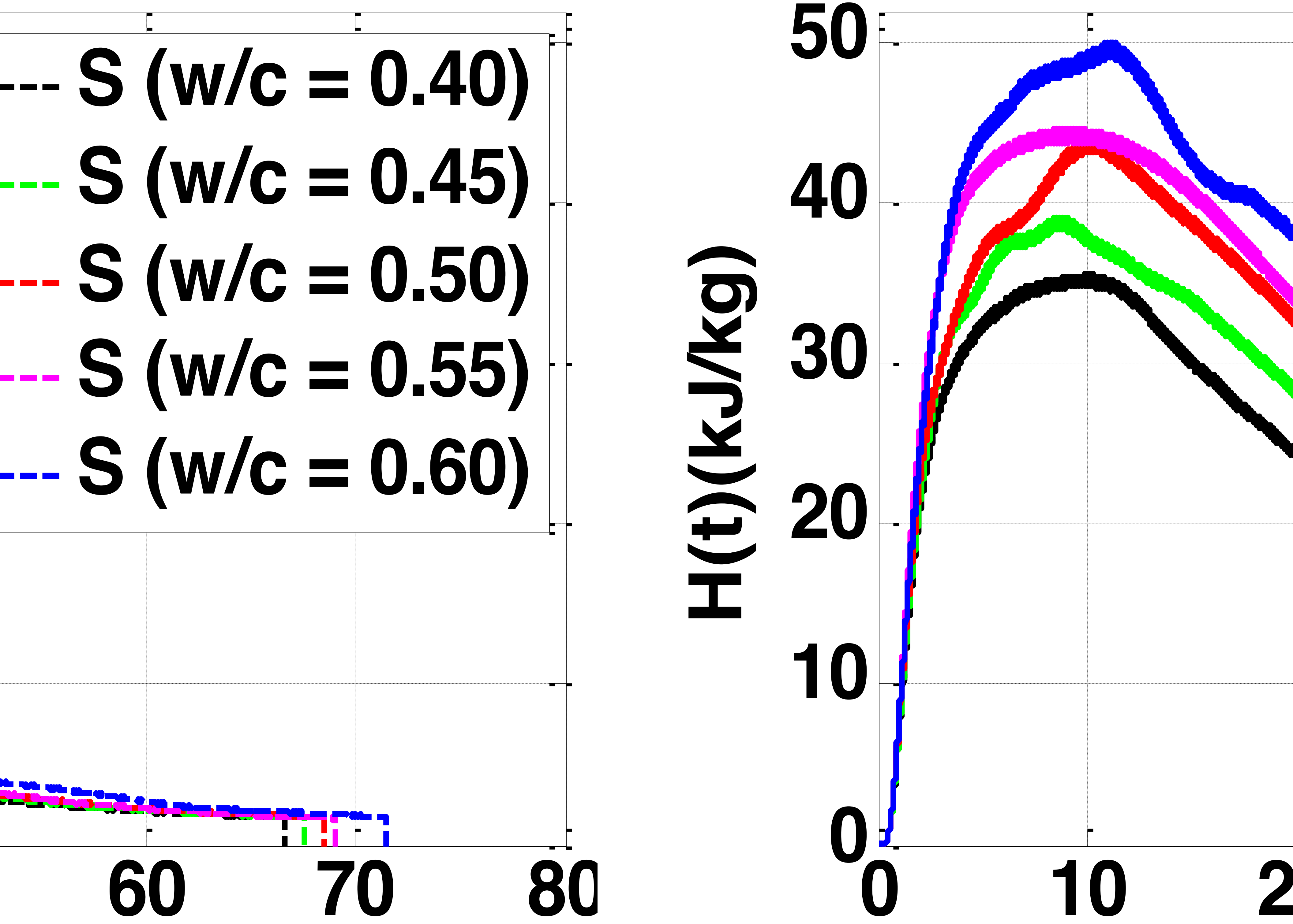
S (w/c = 0.50)
C (w/c = 0.50)
0
10
20
30
40
0
10
20
30
40
50
60
70
80
t_e (hr)



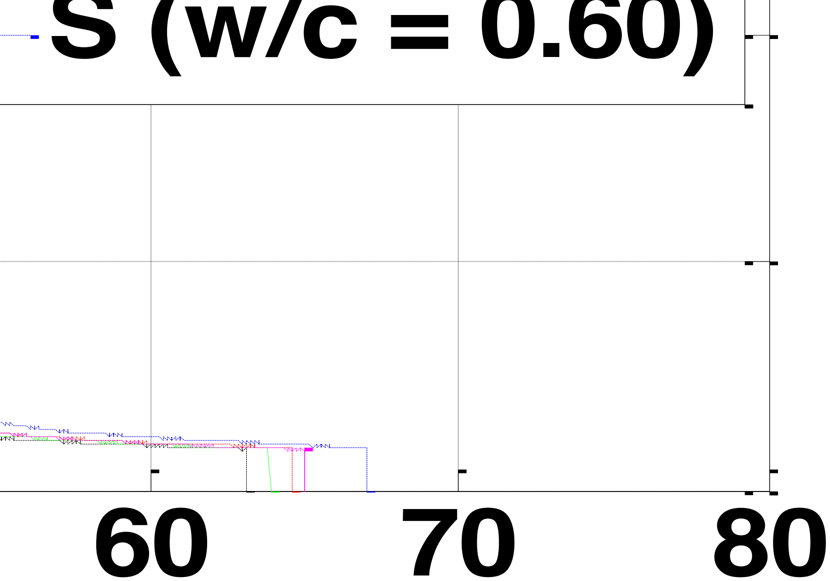
S (w/c = 0.40)
S (w/c = 0.45)
S (w/c = 0.50)
S (w/c = 0.55)
S (w/c = 0.60)
60
70
80
H(t)(kJ/kg)
40
30
20
10
0
0
10



S (w/c = 0.50)
C (w/c = 0.50)
H(t)(kJ/kg)
0
10
20
30
40
50
0
10
20
30
40
50
60
70
t_e (hr)



S (w/c = 0.40)
S (w/c = 0.45)
S (w/c = 0.50)
S (w/c = 0.55)
S (w/c = 0.60)
60
70
80
H(t)(kJ/kg)
50
40
30
20
10
0
0
10



of concrete
9000 J/mol)

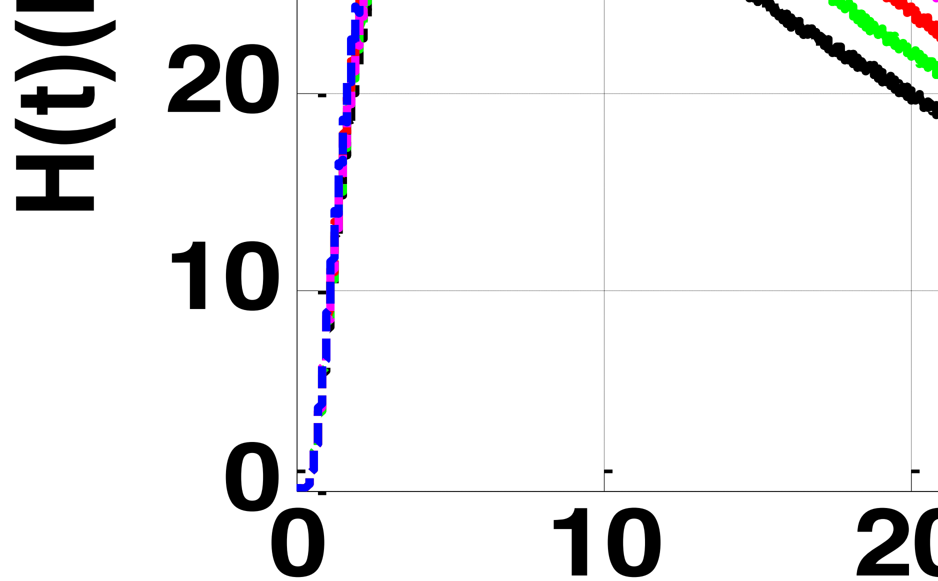
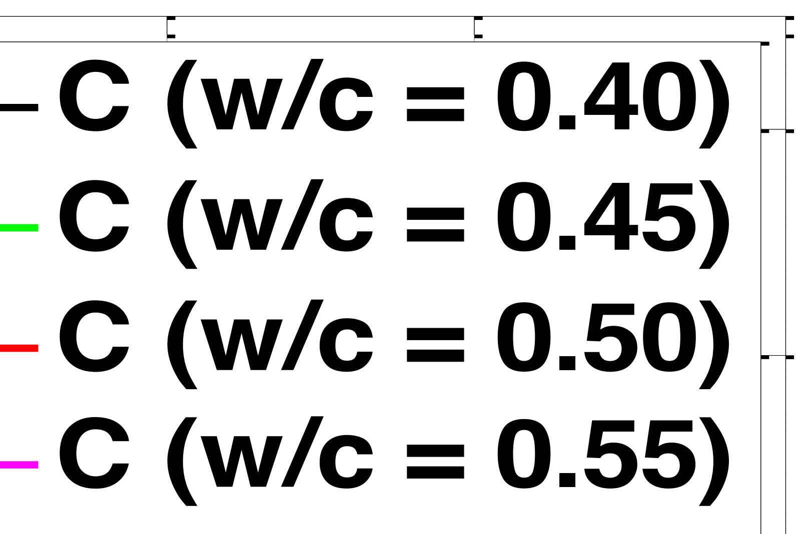
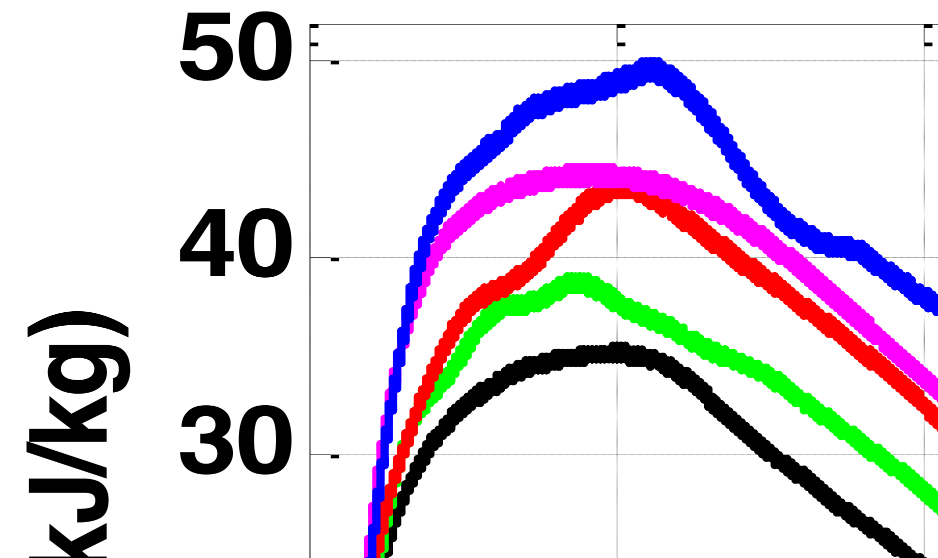


Figure 34. F
specimens





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ON ENERGY

nent within concrete cylinders was pr
ased on ambient conditions during th
duced inaccurate temperature measur
fered by environmental conditions.
Perot fiber optic temperature sensor p

et:
acement, the development of surface
temperature inside the glass chambe

°C	t (hr)	°C
51.42	13.52	59.3
52.88	14.16	52.4
55.08	15.24	57.1

ture of 3”×6” concrete specimens

	0.4	**0.45**	**0.5**

First Approach

$_{max}$ are determined to be **29.21 kJ/m**

o give up in order to overcome the re
0.40), **1.129 kJ/mol** (w/c = 0.50) an
1.16 kJ/kg.

are found to be **29.97 kJ/mol** and

/4 **kJ/kg** and **38.778 kJ/kg** at the sur

proportional to apparent activation e

s w/c increases.

nd heat of hydration are dependent o

Second Approach

ves induce double peaks, this occurre

4”x8”	3’
H(t) kJ/kg	$H(t)_{surface}$ kJ/kg
51.16	35.27
55.00	32.70
70.40	35.74

ach and the second approach (with
tion are only slightly different. Thi

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nd setups last 70 hours and 45 hours

d heat of hydration were studied bas

on real-time measurement, and (b) th

greement and considered to be reliab

temperature measurement in all expe
nniques are implemented.

this research is a novel EP sensor in

his guidance in the determinati

m Electrical and Computer Eng

ty to collaborate with her PhD

r performing my experiments.

ing a very helpful partner. He c

ng in my concrete experimenta

ANK YO