75 years
of the Silesian University
of Technology

Silesian
University
of Technology

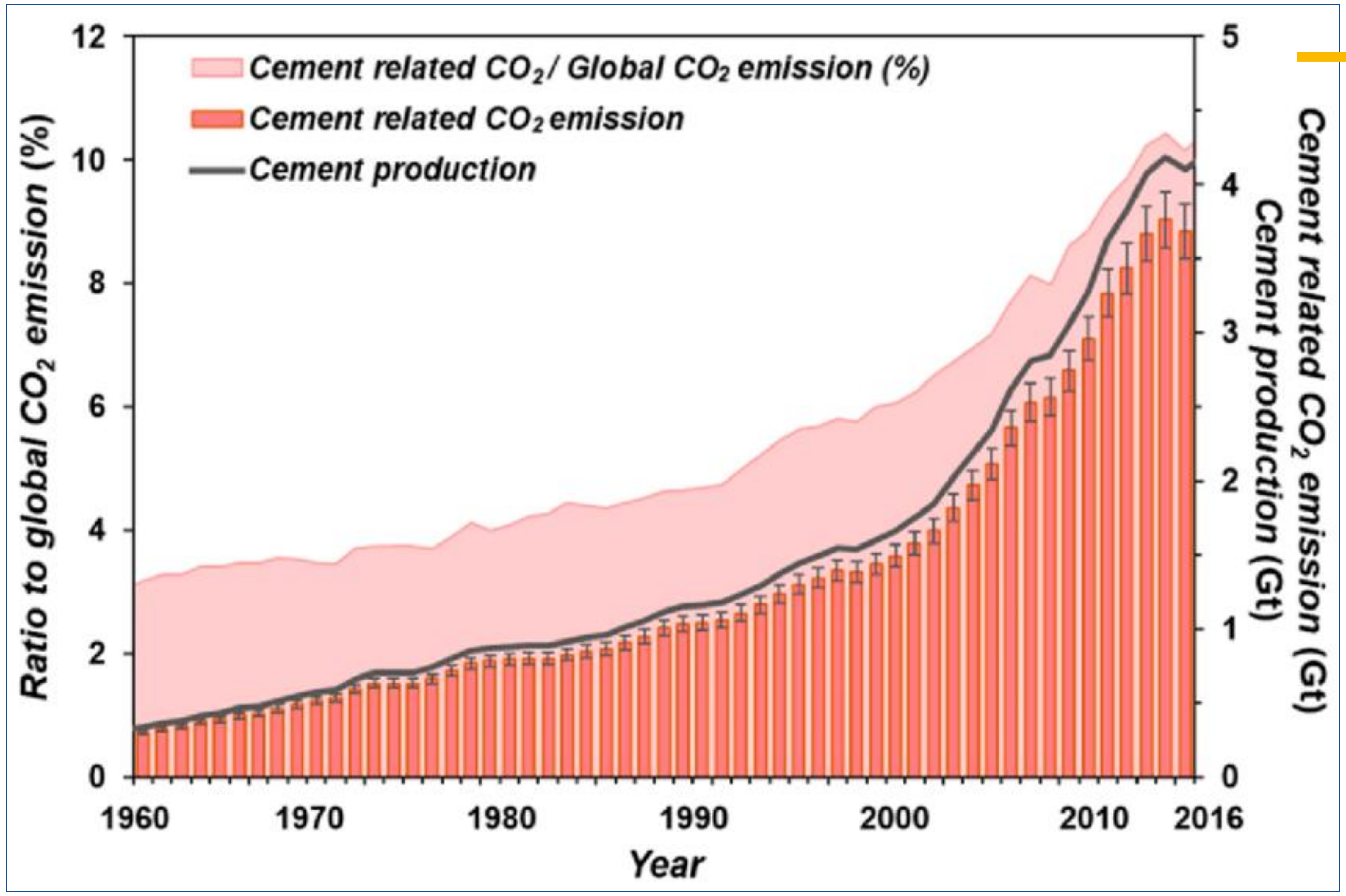
RESEARCH
UNIVERSITY
EXCELLENCE INITIATIVE

RHEOLOGICAL PROPERTIES OF CALCIUM-SULFOALUMINATE CEMENT MORTARS

MAŁGORZATA GOŁASZEWSKA, PhD
Prof. JACEK GOŁASZEWSKI, PhD, DSc

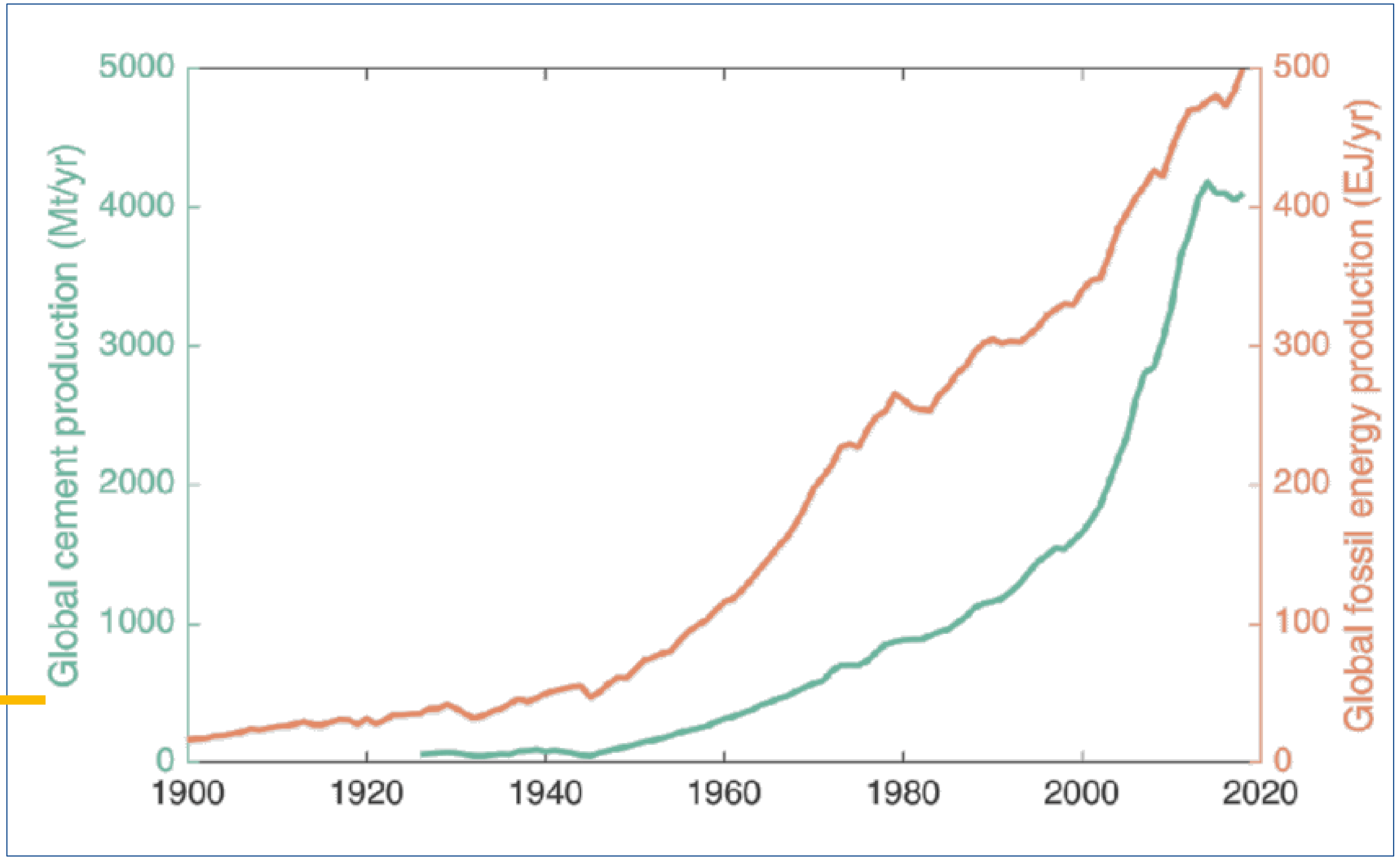
INTRODUCTION

CSA CEMENTS



CO_2 Emissions related to the production of cement and its ratio to total CO_2 emissions.

Source: United States Geological Survey (USGS). Cement Statistics and Information.



Global cement production

Source: Andrew, Robbie. (2019). Global CO2 emissions from cement production, 1928–2018. Earth System Science Data Discussions. 1-67.

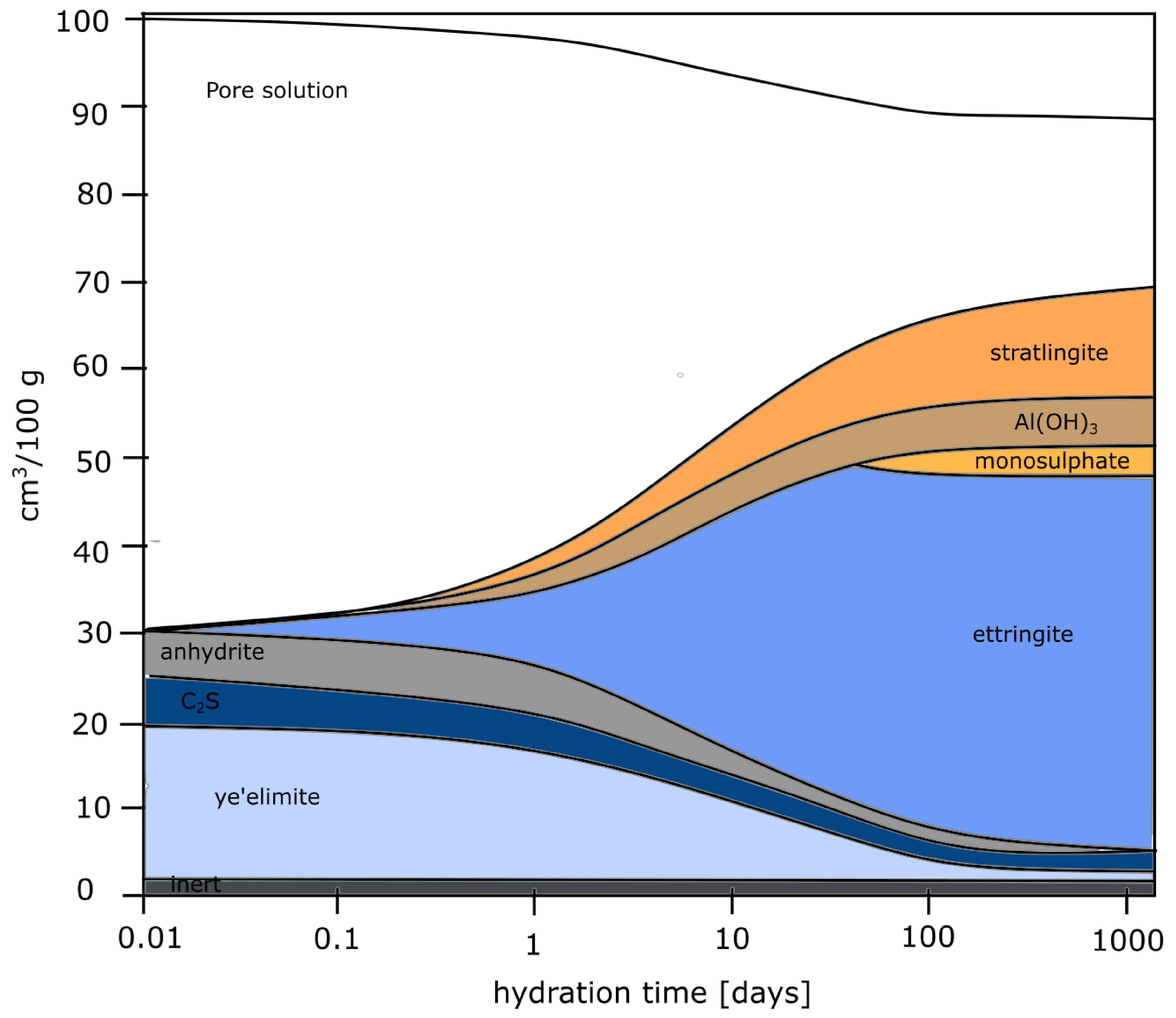
CO_2 EMISSIONS IN CEMENT PRODUCTION

CO_2 from limestone calcination	~550 kg/t clinker	*Source: Gartner, Ellis, Barcelo, Laurent. (2012). The sustainability of cement and concrete*
CO_2 from fuel combustion	~300 kg/t clinker	
	=	
CO_2 emissions for clinker	**~850 kg/t clinker**	
	x	
Average clinker content in cement	72.3%	*Source: Cembureau report (2018)*
	=	
CO_2 emissions for cement	**~615 kg/t cement**	

CO_2 EMISSIONS IN CEMENT PRODUCTION

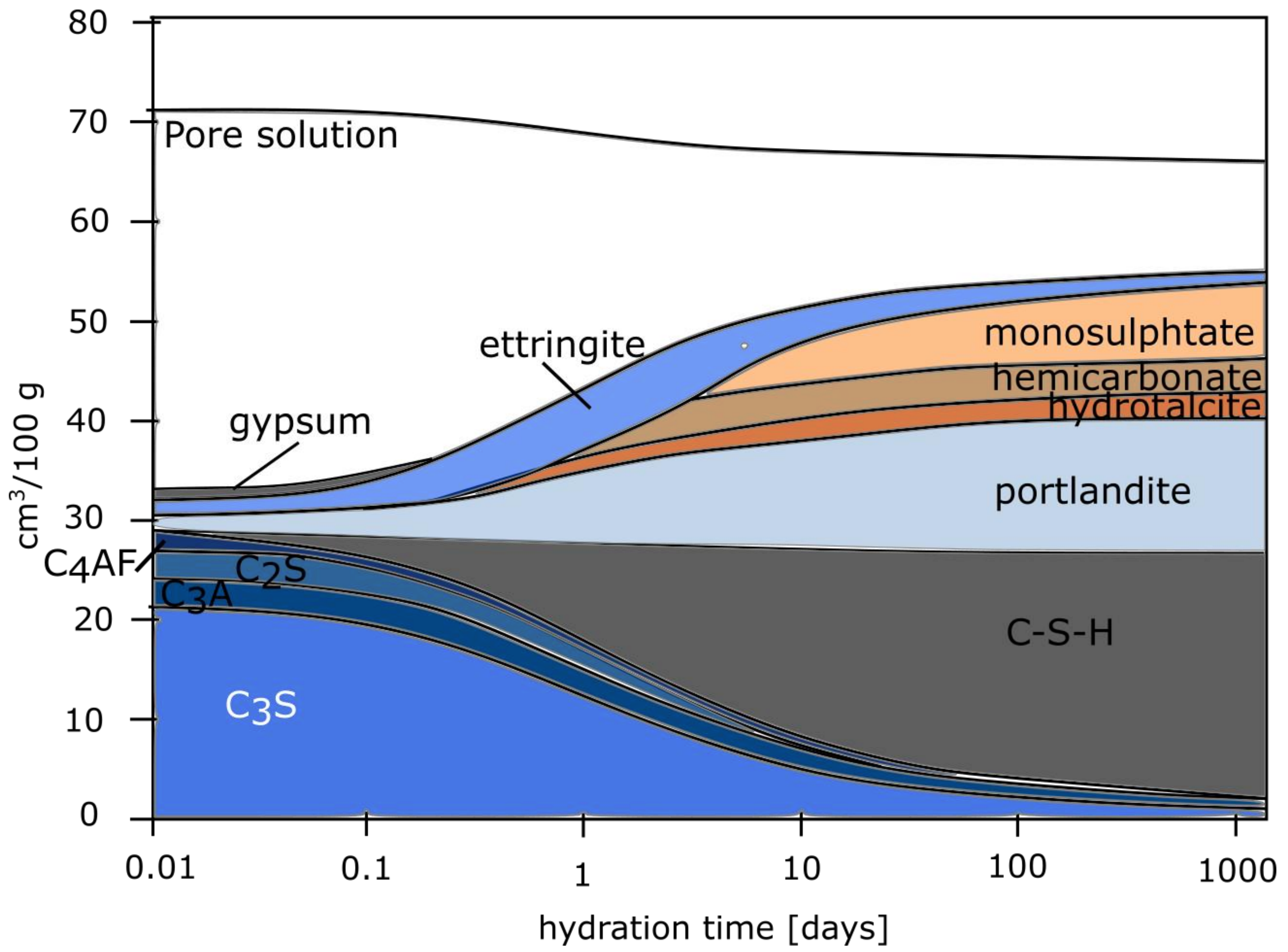
CO_2 from limestone calcination	~550 kg/t clinker ?	*Source: Gartner, Ellis, Barcelo, Laurent. (2012). The sustainability of cement and concrete*
CO_2 from fuel combustion	~300 kg/t clinker	
	=	
CO_2 emissions for clinker	**~850 kg/t clinker**	
	x	
Average clinker content in cement	72.3%	*Source: Cembureau report (2018)*
	=	
CO_2 emissions for cement	**~615 kg/t cement**	

CALCIUM-SULFOALUMINATE CEMENT



CSA CEMENT HYDRATION

Winnefeld, F., Kaufmann, J., Concrete produced with calcium sulfoaluminate cement – a potential system for energy and heat storage, 1st Middle East Conf. Smart Monit. Assess. Rehabil. Civ. Struct. (2011) 1–9.



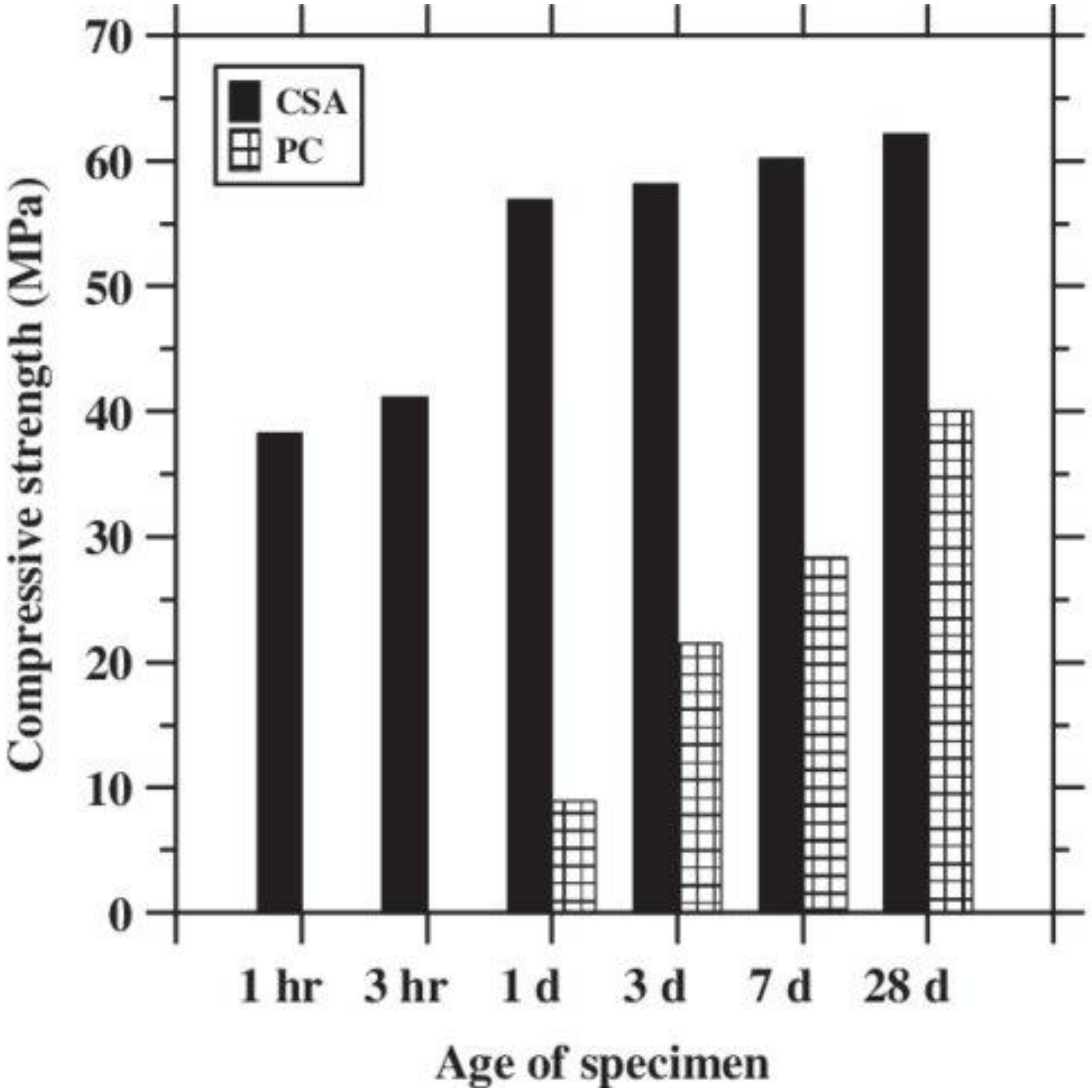
PORTLAND CEMENT HYDRATION

Source: Lothenbach, B., Saout, G. Le, Gallucci, E., Scrivener, K., Influence of limestone on the hydration of {Portland} cements, Cem. Concr. Res. (2008) 848–860.

CALCIUM-SULFOALUMINATE CEMENT

Characteristics:

- Rapid setting time,
- High early strength,
- Low shrinkage,
- High density,
- Lower CO_2 emissions from clinker



Hong, Seongwon & De Bruyn, Kyle & Bescher, Eric & Ramseyer, Chris & Kang, Thomas. (2018). Porosimetric features of calcium sulfoaluminate and Portland cement pastes: testing protocols and data analysis. Journal of Structural Integrity and Maintenance. 3. 52-66.

COMPARISON OF CO_2 EMISSIONS

	PORTLAND CLINKER	CSA CLINKER
CO_2 from limestone calcination	~550 kg/t	~370 kg/t
CO_2 from fuel combustion	~300 kg/t	~240 kg/t
	=	=
CO_2 emissions for clinker	**~850 kg/t**	**~610 kg/t**

Source: Gartner, Ellis, Barcelo, Laurent. (2012). The sustainability of cement and concrete

CALCIUM-SULFOALUMINATE CEMENT

Characteristics:

- Rapid setting time,
- High early strength,
- Low shrinkage,
- High density,
- Lower CO_2 emissions from clinker
- **High cost**

Input (weight %)
12.2% bauxite 68.4% limestone 19.5% clay
6.6% bauxite 67.3% limestone 26.1% clay

Galan, Isabel & Elhoweris, Ammar & Hanein, Theodore & Bannerman, Marcus & Glasser, Fredrik. (2017). Advances in clinkering technology of calcium sulfoaluminate cement. Advances in Cement Research. 29. 1-13.

The aim of the presented study was to investigate chosen properties of mortars with CSA blends with CEM I 42,5R and limestone in amount 10, 20, and 30% of binder mass.

MATERIALS AND METHODS

11

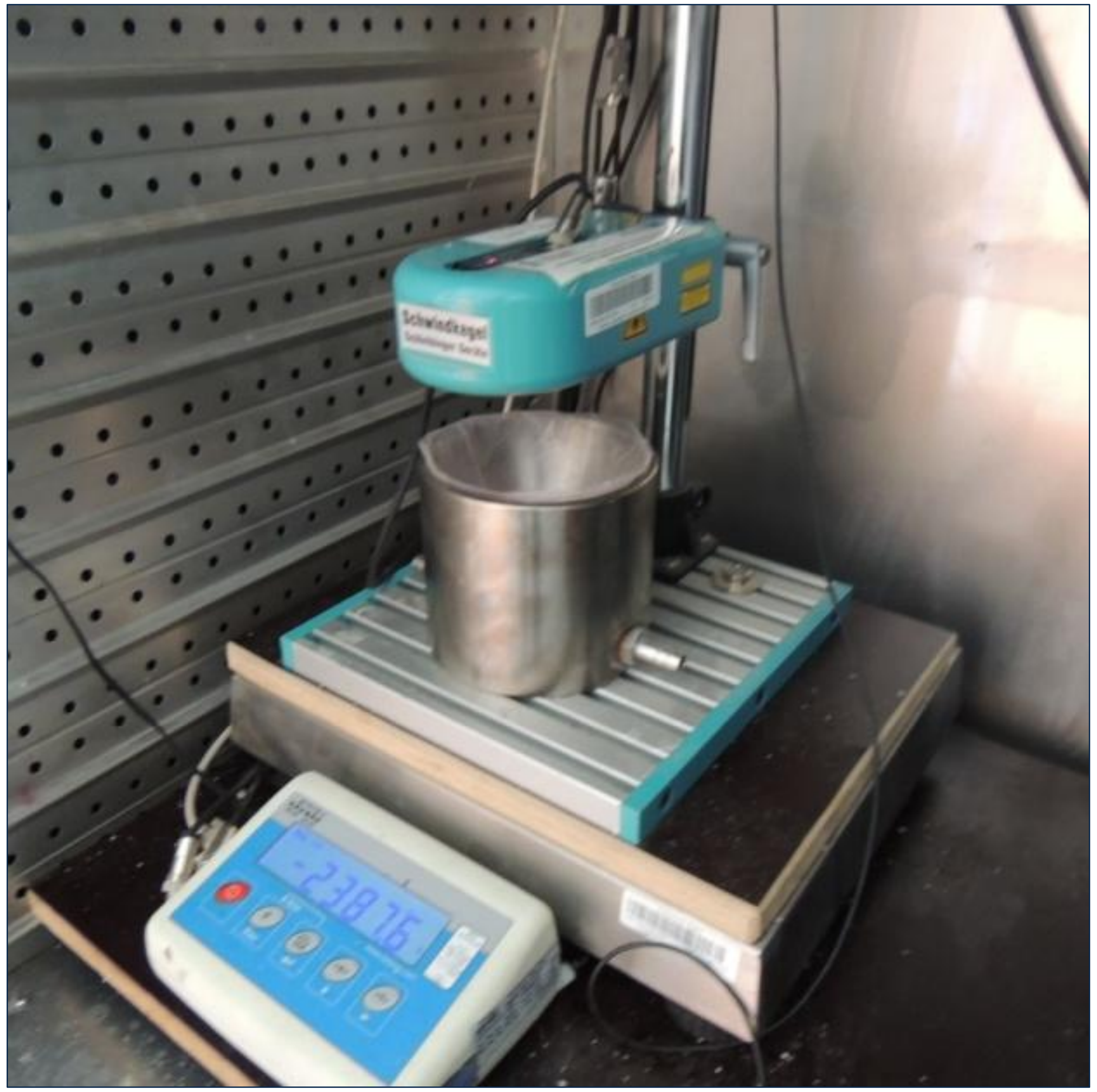
MATERIALS

Cement type	Constituent [%]									
	LOI	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	Na_2O_{eq}
CSA	0.46	9.2	28.1	1.52	39.2	3.5	11.4	0.08	0.35	-
CEM I 42,5R NA	2.8	20.55	4.67	2.8	64.35	1.18	2.79	0.18	0.43	0.46
Limestone MW	42.7	1.4	0.4	0.5	53.2	1.5	0.02	-	-	-

CSA CEMENT + 10, 20, 30% CEM I 42.5R NA

CSA CEMENT + 10, 20, 30% LIMESTONE MW

METHODS – EARLY SHRINKAGE

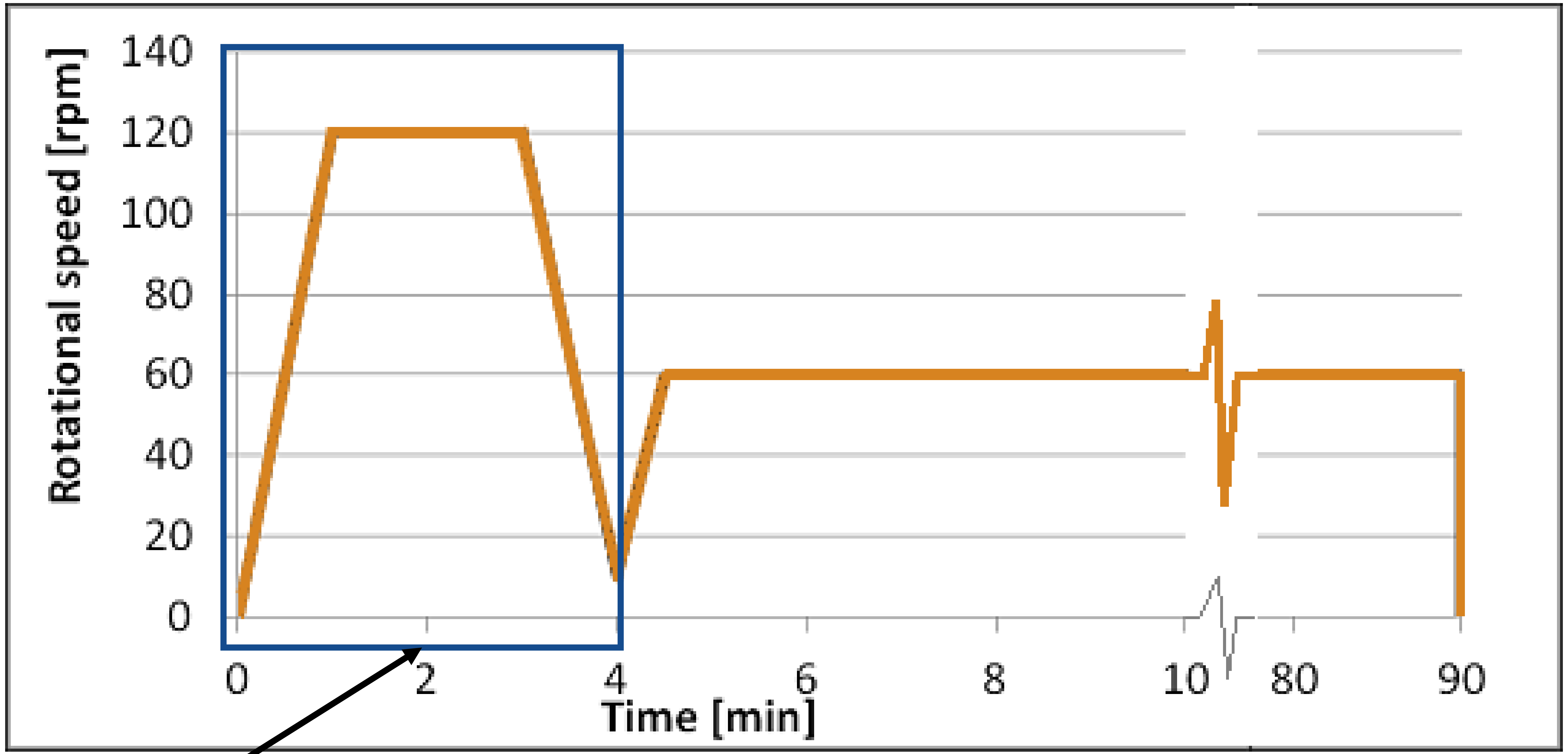


- Schleibinger Shrinkage Cone deltaEL,
- Early shrinkage measured from 5 min from mixing the mortar,
- Measurement lasted 24 h,
- During the measurement, sample was kept in a climatic chamber in 20^{o}C and humidity of 60%

METHODS – RHEOLOGICAL MEASUREMENT

- Schleibinger Viskomat NT,
- Measurement lasted 1.5 h,
- Measured were plastic viscosity and yield stress after 5 min from mixing, and changes in torque,
- During the measurement, sample was kept in temperature of 20^{o}C

METHODS – RHEOLOGICAL MEASUREMENT



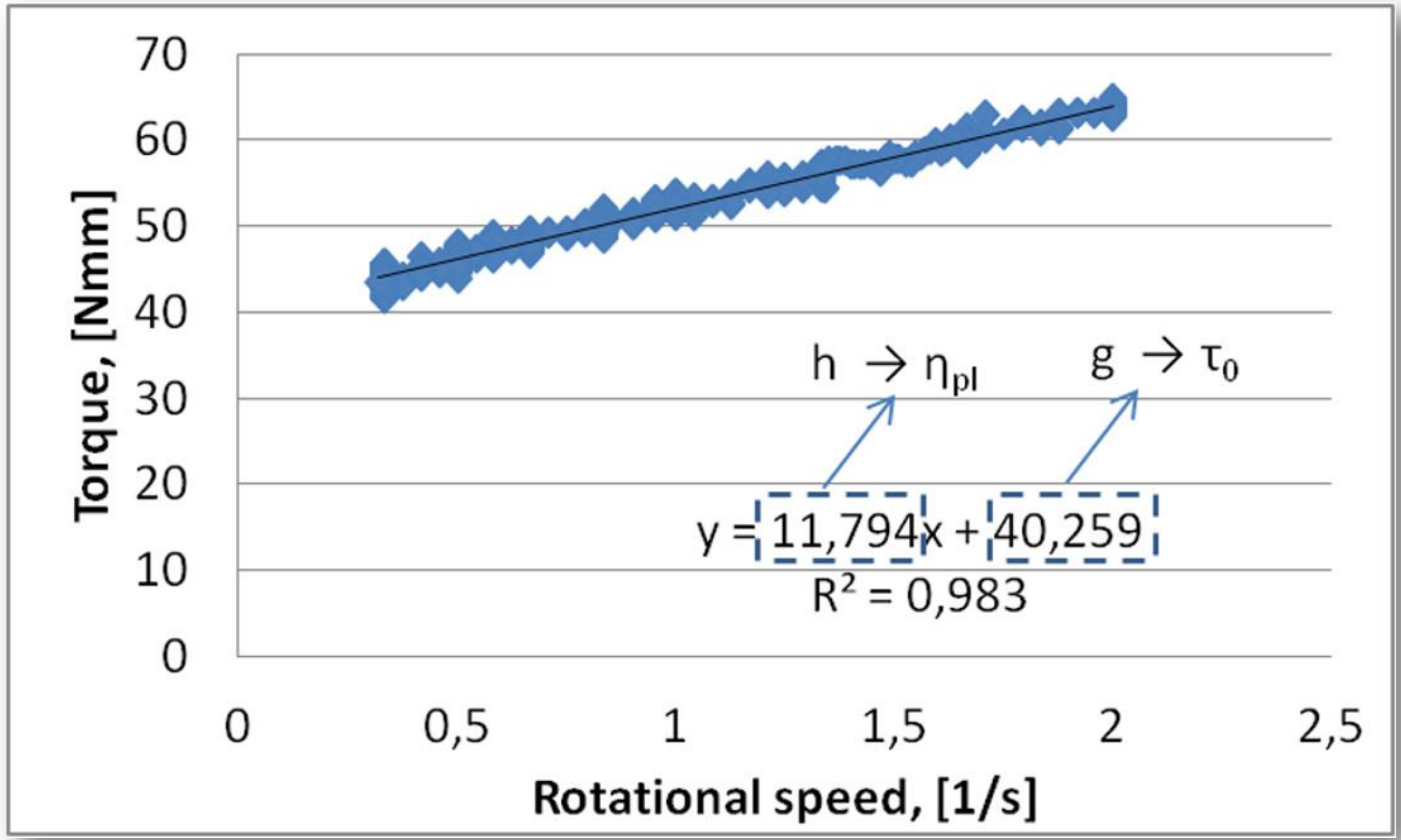
Measurement of yield stress and plastic viscosity

METHODS – RHEOLOGICAL MEASUREMENT

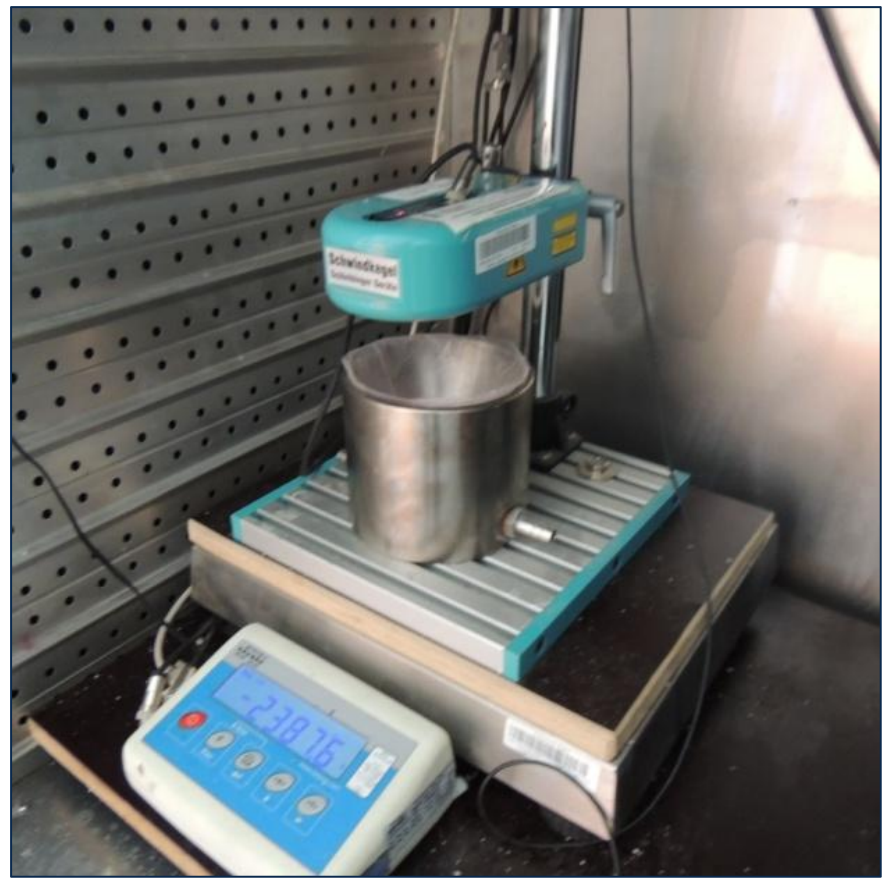
Rheological parameters were obtained using simplified Bingham model:

$$M = g + hN$$

M – torque,
N – rotational speed
g – shear resistance → yield stress τ_0
h – plastic flow resistance → plastic viscosity η_{pl}



MORTARS USED IN THE RESEARCH

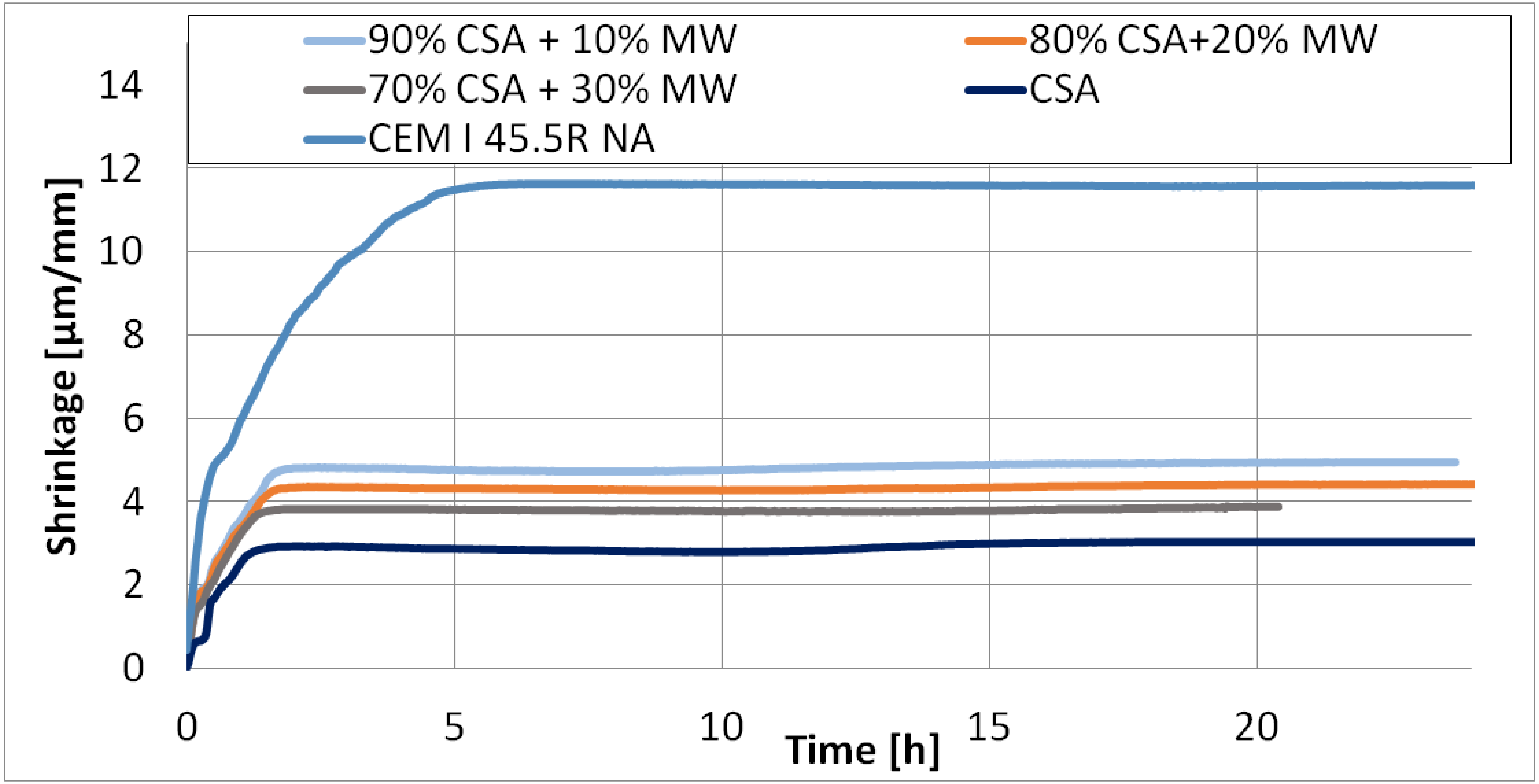


	CEMENT [g]	ADDITION AMOUNT	LIMESTONE OR CEM I 42.5 R NA [g]	STANDARD SAND [g]	W/C RATIO	WATER [g]
CSA cement	450	0%	-	1350	0.5	225
	423	6%	27			
	405	10%	45			
	360	20%	90			
	315	30%	135			

	CEMENT [g]	ADDITION AMOUNT	LIMESTONE OR CEM I 42.5 R NA [g]	STANDARD SAND [g]	W/C RATIO	WATER [g]
CSA cement	450	0%	-	1350	0.6	270
	423	6%	27			
	405	10%	45			
	360	20%	90			
	315	30%	135			

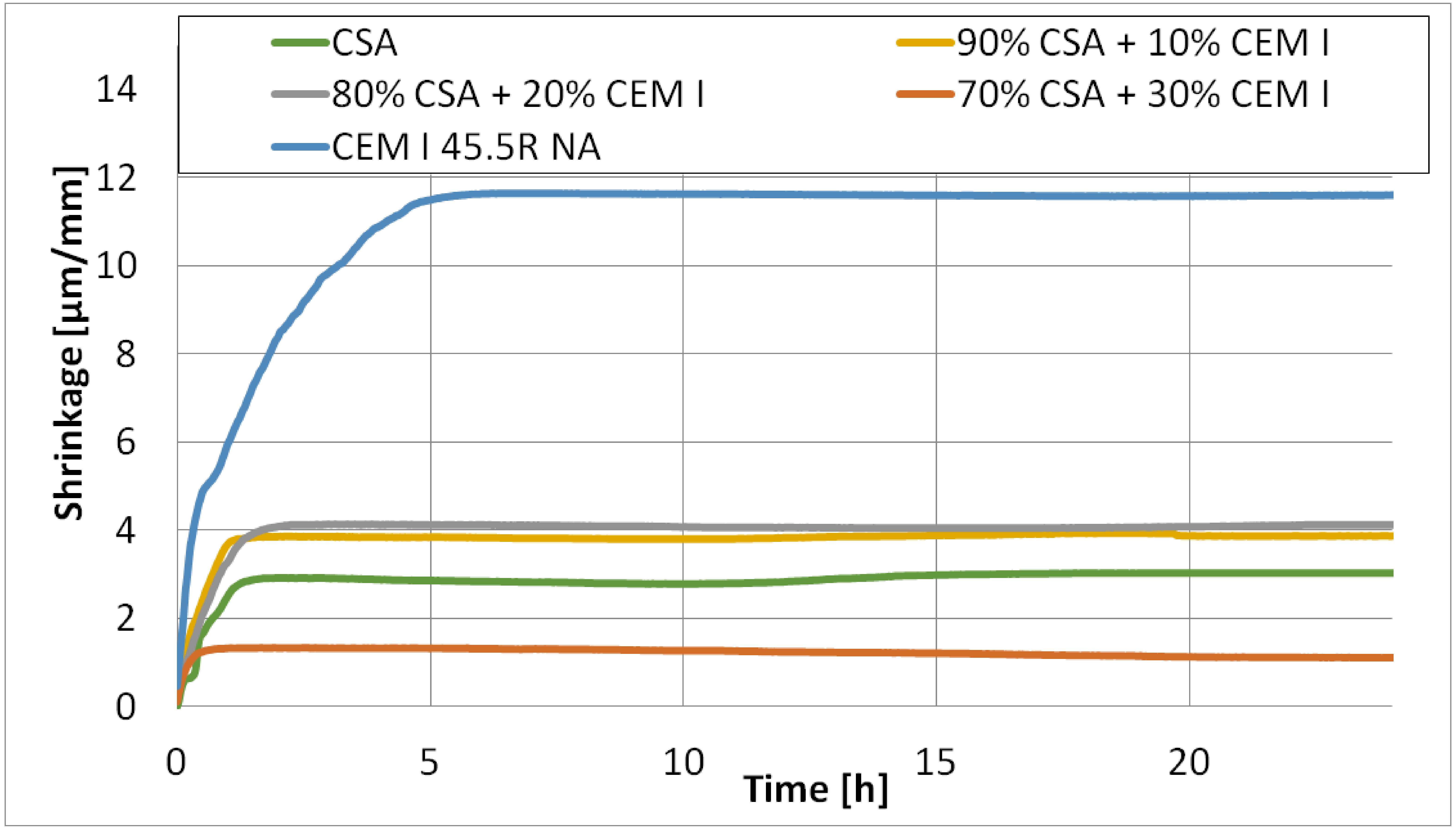
RESULTS

SHRINKAGE



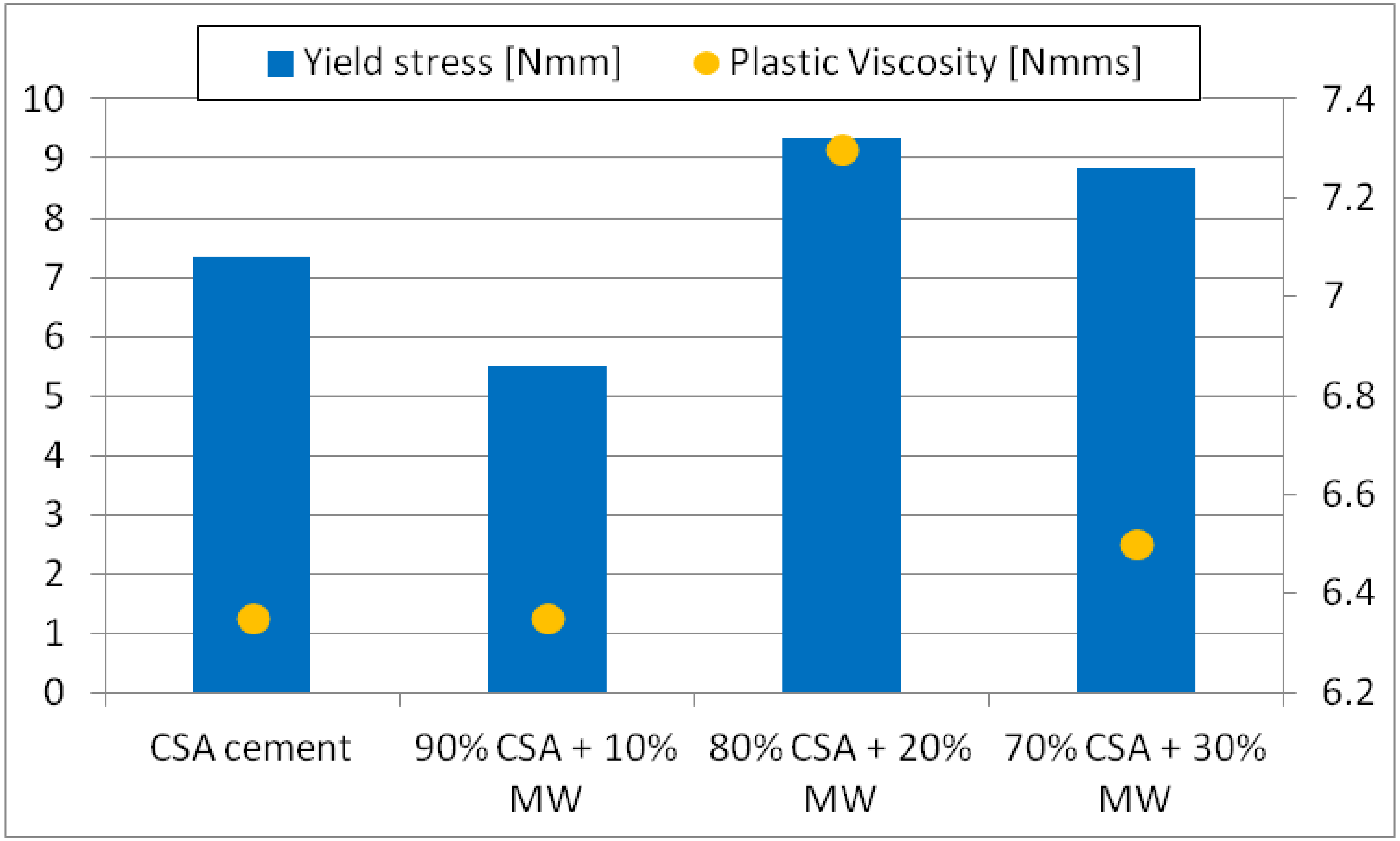
90% CSA + 10% MW
80% CSA+20% MW
70% CSA + 30% MW
CSA
CEM I 45.5R NA
Shrinkage [µm/mm]
0
2
4
6
8
10
12
14
0
5
10
15
20
Time [h]

SHRINKAGE

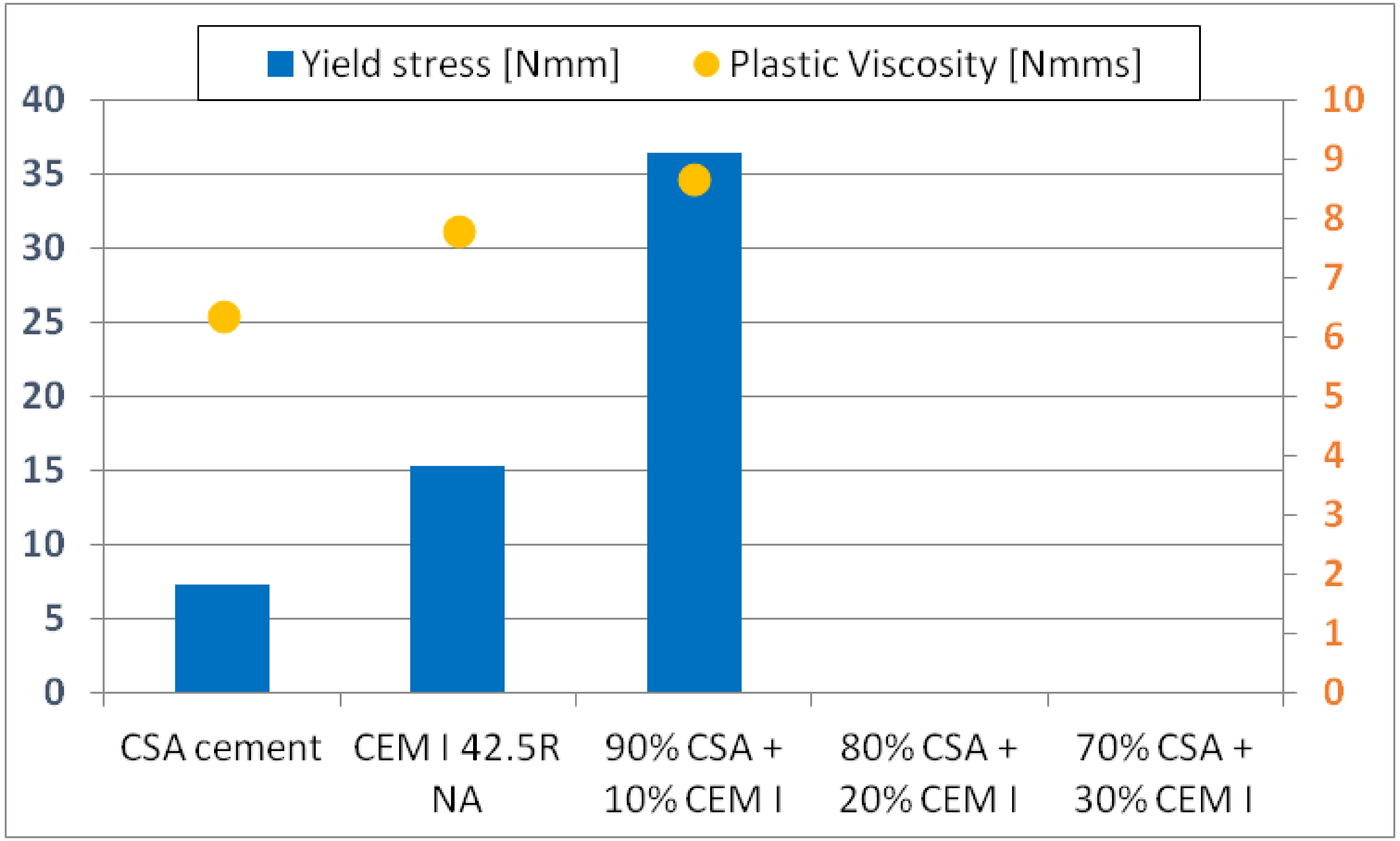


CSA
90% CSA + 10% CEM I
80% CSA + 20% CEM I
70% CSA + 30% CEM I
CEM I 45.5R NA
Shrinkage [µm/mm]
14
12
10
8
6
4
2
0
0
5
10
15
20
Time [h]

RHEOLOGICAL MEASUREMENT

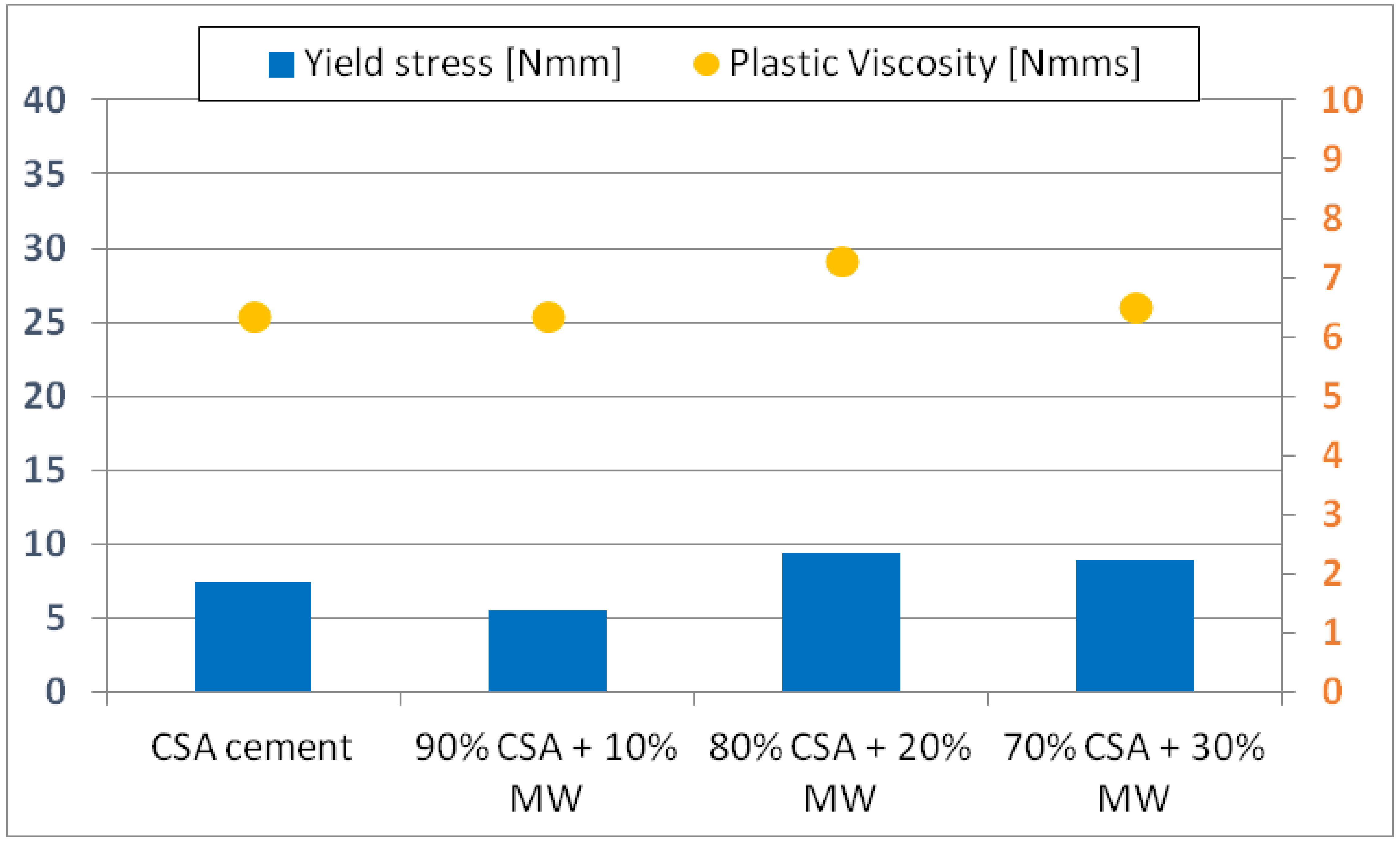


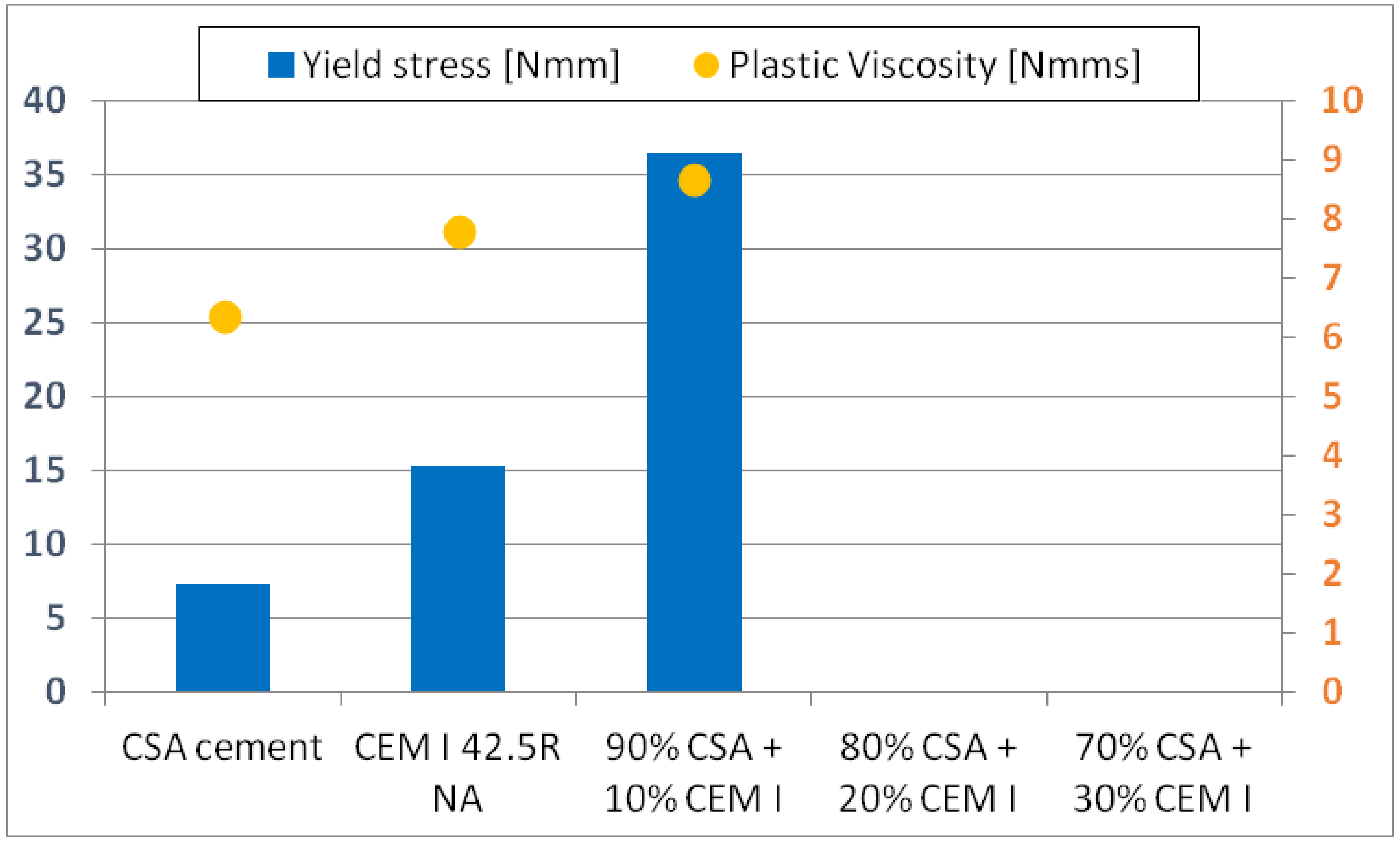
RHEOLOGICAL MEASUREMENT



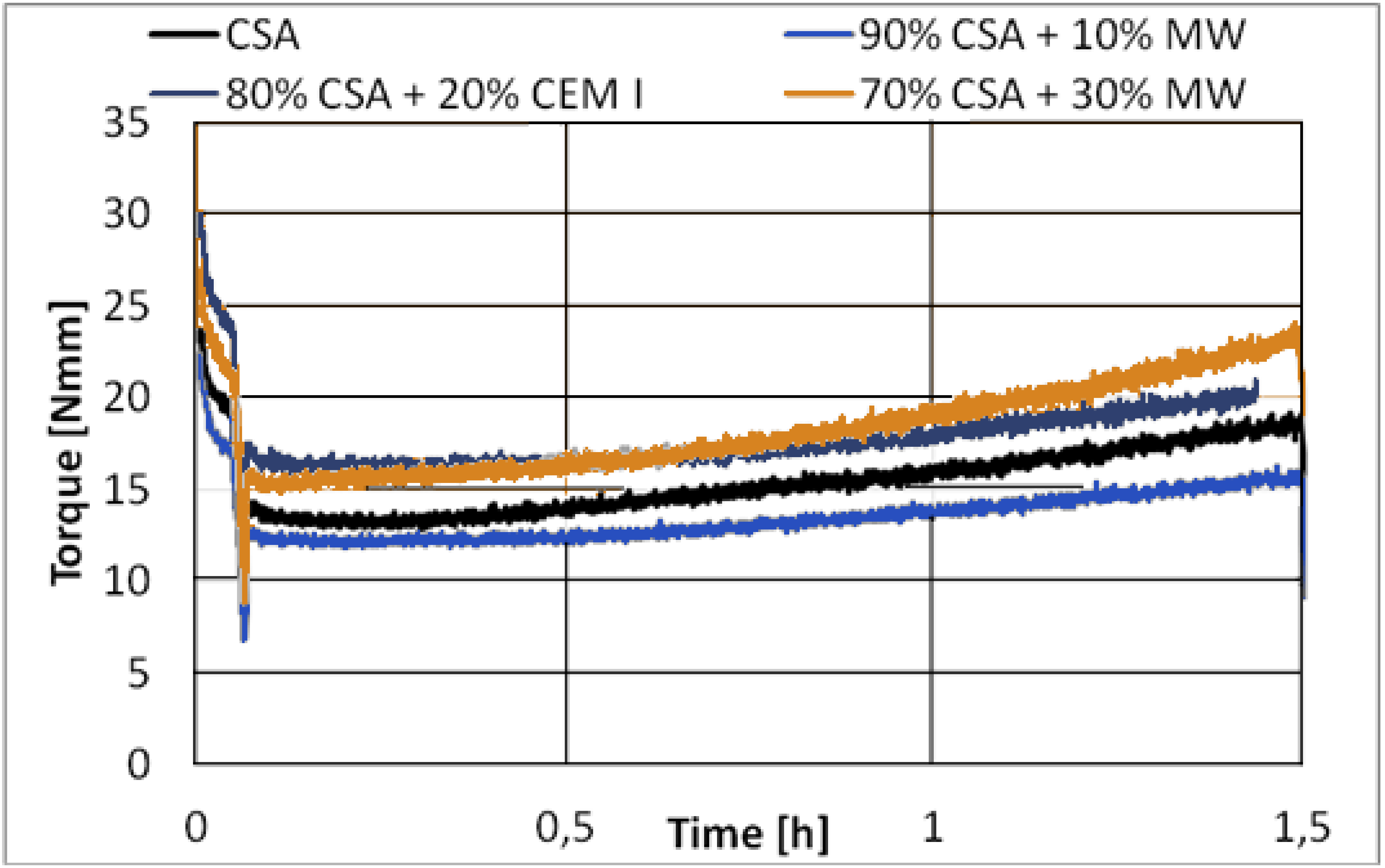
Silesian University of Technology

RHEOLOGICAL MEASUREMENT

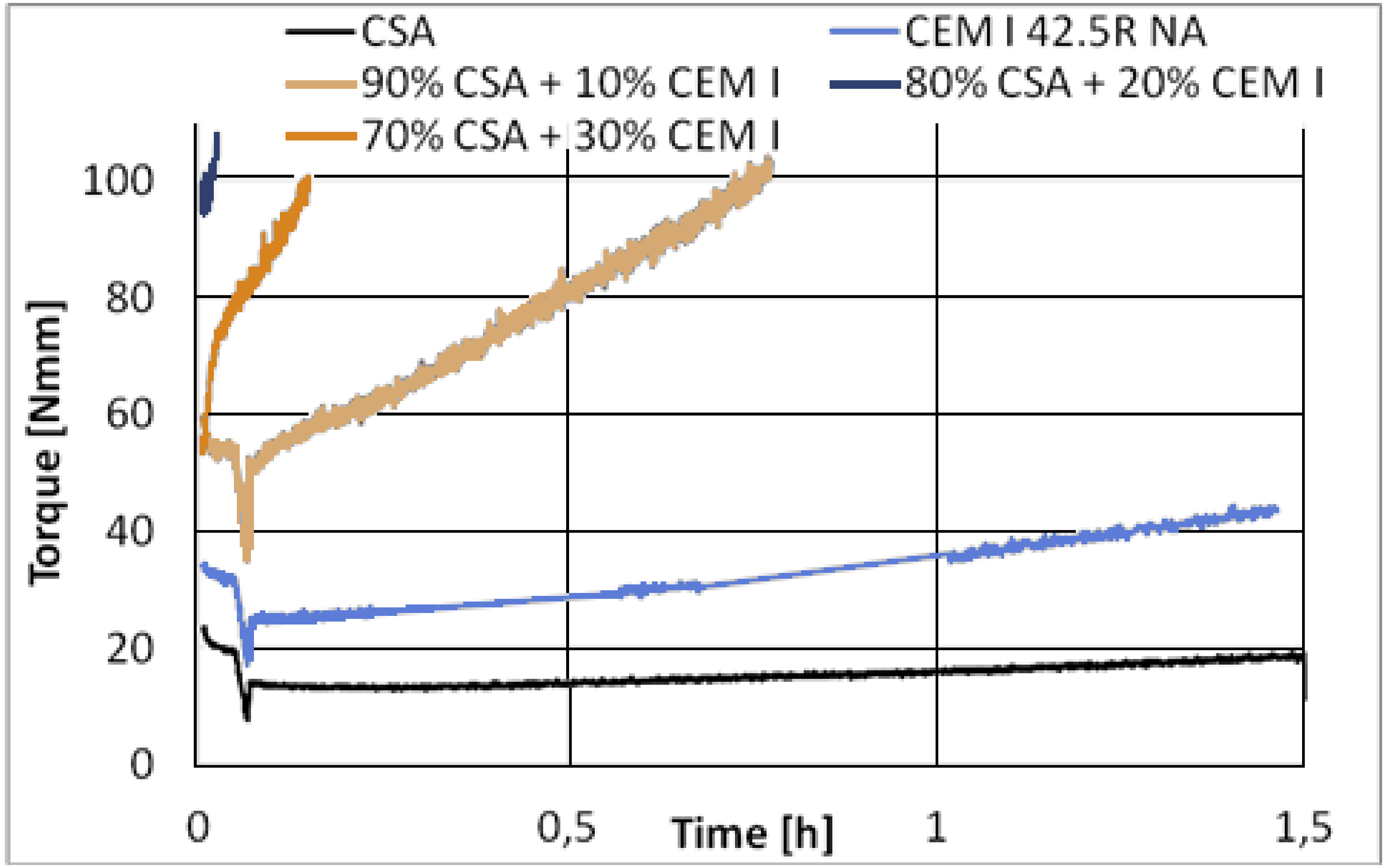




RHEOLOGICAL MEASUREMENT



RHEOLOGICAL MEASUREMENT



CONCLUSIONS

CONCLUSIONS

- Substitution of 10-30% of CSA cement mass with CEM I 42.5R NA led to increase in yield stress and torque, of mortars, and rapid loss of consistency. This effect may occur due to 'flash setting' of Portland cement in the presence of CSA cement. Similar effects were not observed in case of limestone

- Addition of 10% of limestone slightly decreased the torque and yield stress, what may be due to the filler effect, which leads to limestone particles acting as a bearing for clinker and sand particles. Addition of 20% and 30% of limestone led to a small increase.

- CSA cements were characterized by significantly lower shrinkage than Portland cement CEM I 42.5R NA. Shrinkage of CSA cements with limestone are slightly higher than of CSA cement. This might be due to the higher capillary forces, due to the filler effect of limestone. In case of CSA cement with 30% substitution with Portland cement, a further decrease in shrinkage was observed. This might be due to the expansive forms of ettringite that may appear during hydration of CSA cement in the presence of Portland clinker.

THANK FOR YOUR ATTENTION

E-mail
Malgorzata.golaszewska@polsl.pl