BOLETÍN DE LA SOCIEDAD ESPAÑOLA DE CERÁMICA Y VIDRIO 54 (2015) 45–57

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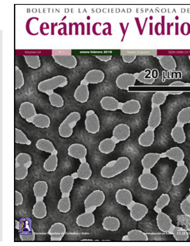
Cerámica y Vidrio



Alkali activated slag cements using waste glass as alternative activators. Rheological behaviour

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ARTICLE INFO

Article history:
Received 19 January 2015
Accepted 25 February 2015

Keywords:
Waste glass
Alternative activators
Alkali-activated materials
Rheology
Yield stress

A B S T R A C T

The purpose of this study is to investigate news activators in the preparation of alkali-activated materials (AAMs) alternative to Portland cements by reusing waste glass. Alkali-activated blast furnace slag (AAS) constitutes an alternative to Portland cement due to high energy and environmental pollution associated with industrial Portland cement. Moreover, alkali activated materials offer a series of higher properties than ordinary Portland cement (OPC), such as better strength and durability behaviour. However, the rheology of these materials has been much less intensely researched.

The present study aimed to study the effect of waste glass as activator and as replacement of blast furnace slag on the rheological behaviour of AAS pastes, with a comparison between the rheological parameters and fluidity of these pastes to the same parameters in standard cements (CEM I and CEM III/B).

The findings show that AAS paste behaviour of rheology when the activator was a commercial waterglass solution or $NaOH/Na_2CO_3$ with waste glass was similar, fit the Herschel-Bulkley model. The formation of primary C-S-H gel in both cases were confirmed. However, the rheological behaviour in standard cements fit the Bingham model. The use of the waste glass may be feasible from a rheological point of view in pastes can be used.

Preparación de cementos de escoria activada alcalinamente utilizando residuos vítreos como activador alcalino. Comportamiento reológico

Palabras clave:
Residuos vítreos
Activadores alternativos
Materiales activados alcalinamente

R E S U M E N

El propósito de este estudio es investigar nuevos activadores alcalinos a través de la reutilización de residuos vítreos en la preparación de materiales activados alcalinamente alternativos al cemento Portland (OPC). Las escorias activadas alcalinamente (AAS) son una alternativa al cemento Portland debido a la alta demanda energética y medioambiental

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1150 kg prime material
0.94 kg air

600 kg CO_2
1566 kg N_2
262 kg O_2

63 kg fuel
1050 kg air

Fig. 1 – Mass balance in a typical production process of cement [5].

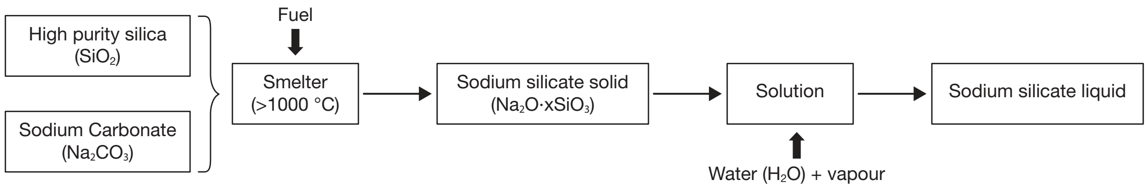

Fig. 2 – Commercial manufacturing process of sodium silicate.

Table 1 – Estimates of emissions arising due to sodium silicate manufacture [20].

	Emissions arising from energy expended during manufacturing	
	Energy flow (MJ/1000 kg)	Emissions (kg CO_2/kg)
Electricity	3118	1.065
Coal	296	0.027
Oil (heavy)	9	0.001
Oil (average/light)	456	0.033
Diesel oil	144	0.010
Gas	1270	0.076
Others	78	0.009
Total	5371	1.222
	Emissions caused by transport	
	Air emissions (kg/1000 kg)	Emissions (kg CO_2/kg)
Carbon dioxide (CO_2)	288.7	0.289
Methane (CH_4)	0.128	0.003
	Total	0.292
	Grand total (kg CO_2/kg)	1.514

wt.%	CaO	SiO_2	Al_2O_3	MgO	Fe_2O_3	S^{2-}	SO_3	Na_2O	K_2O	L.O.I*
Slag	41.00	35.54	13.65	4.11	0.39	1.91	0.06	0.01	-	2.72
Waste glass	11.75	70.71	2.05	1.17	0.52	-	-	11.71	1.08	0.83
CEM I 52.5R	57.05	20.51	5.37	3.86	2.10	-	6.37	0.64	1.44	2.35
CEM III/B 32.5R	49.25	29.91	7.80	6.33	0.95	1.2	1.01	0.33	0.38	2.44

Table 2 – Chemical composition of slag, waste glass and standard cements (wt.%) determined by XRF.

* L.O.I = Loss on ignition.

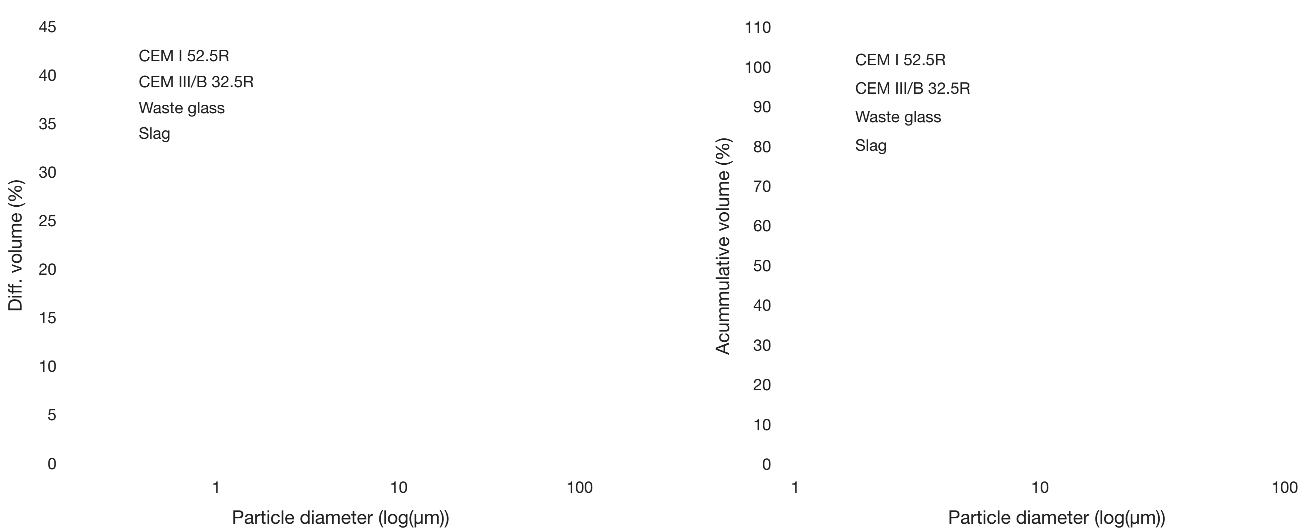

Fig. 3 – Standard cements, slag and waste glass particle size distribution.

Table 3 – Particle size distribution of all materials used.

% volume	Particle diameter (μm)			
	CEM I 52.5R	CEM III/B 32.5R	Slag	Waste Glass
10	1.76	1.88	1.41	2.34
50	9.49	12.61	10.89	12.20
90	29.34	42.03	32.67	35.78
Specific surface (m^2/kg)	481	393	325	-

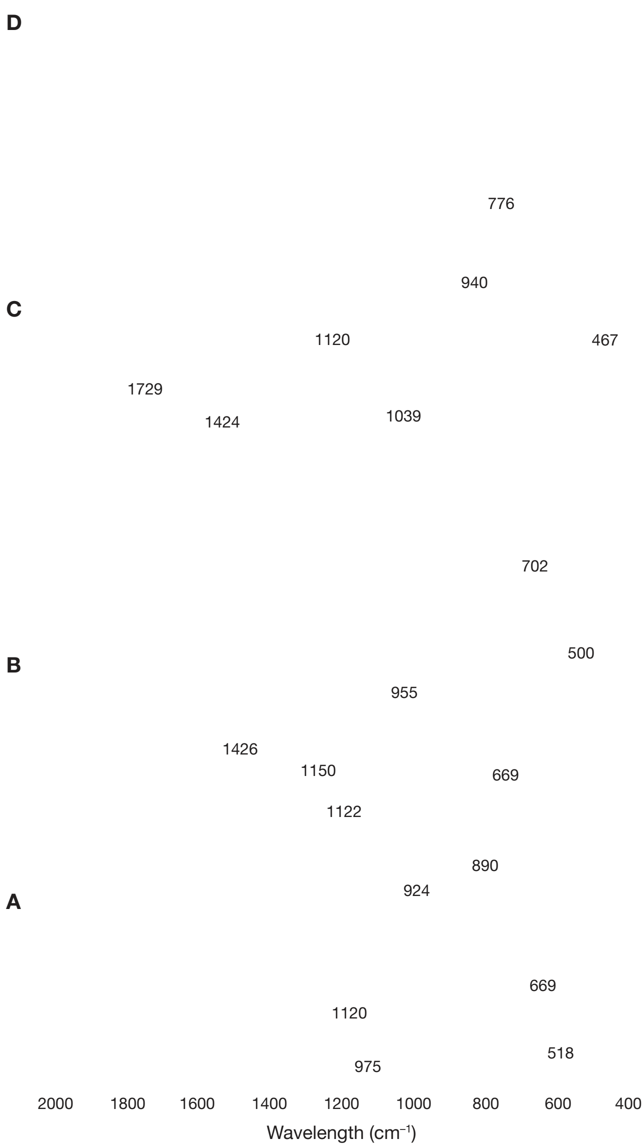

Fig. 4 – FTIR spectra for raw material used: A) CEM III/B 32.5R; B) CEM I 52.5R; C) blast furnace slag; D) waste glass.

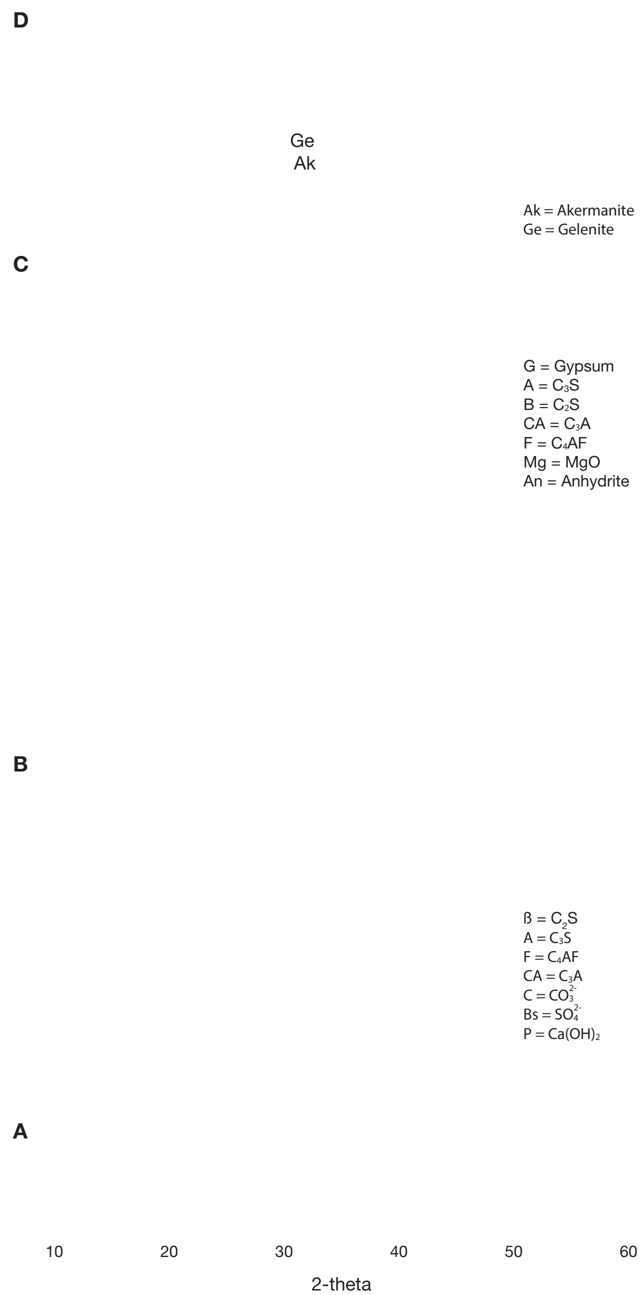

Fig. 5 – XRD patterns for raw material used: A) CEM III/B 32.5R; B) CEM I 52.5R; C) blast furnace slag; D) waste glass.

Sample name	Activator type	SiO_2/Na_2O	L/S
AAS WG	Commercial waterglass	0.86	0.55
AAS N/C-glass	$NaOH/Na_2CO_3$ + waste glass	0.86	0.55
AAS N/C-glass+10%	$NaOH/Na_2CO_3$ + waste glass + 10% residual glass waste	0.86	0.55
CEM I 52.5R	Water	-	0.45
CEM III/B 32.5R	Water	-	0.35

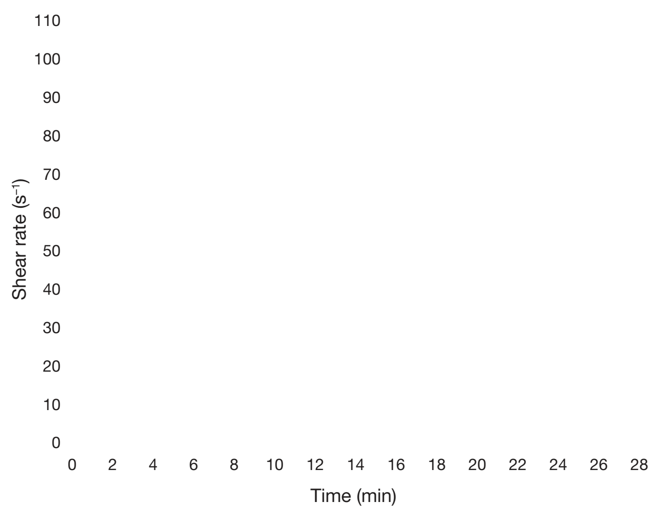

Fig. 6 – Dynamic rheological testing with standard Portland cements and AAS pastes.

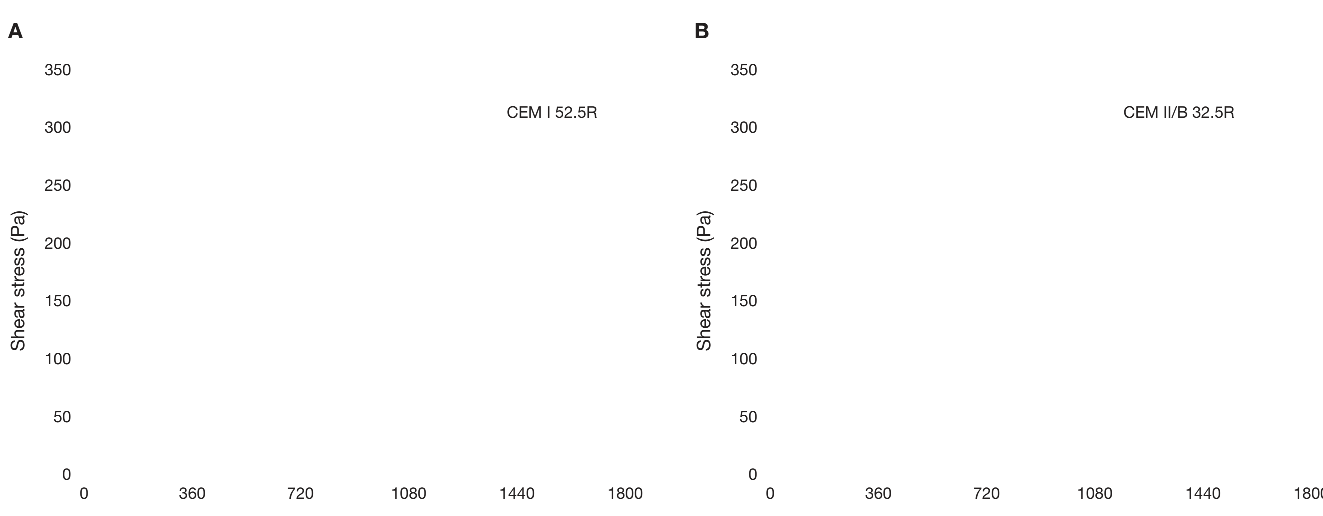

Fig. 7 – Shear stress vs time in standard cements: A) CEM I 52.5R and B) CEM III/B 32.5R.

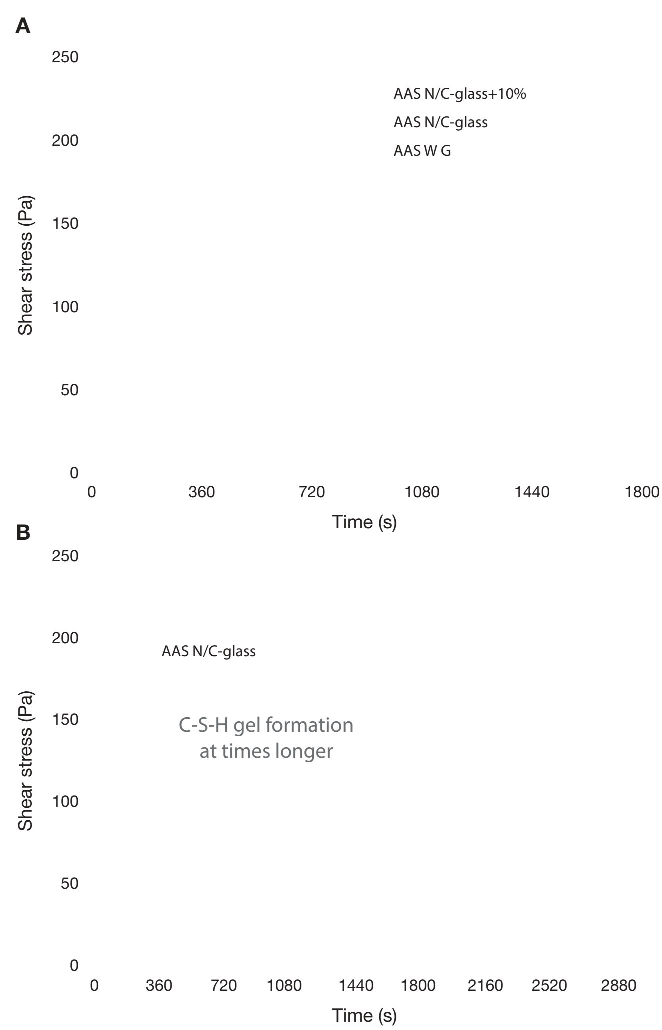

Fig. 8 – Shear stress in alkali activated slag with different activators: A) AAS WG, AAS N/C-glass and AAS N/C-glass+10%; B) AAS N/C-glass+10% at times longer.

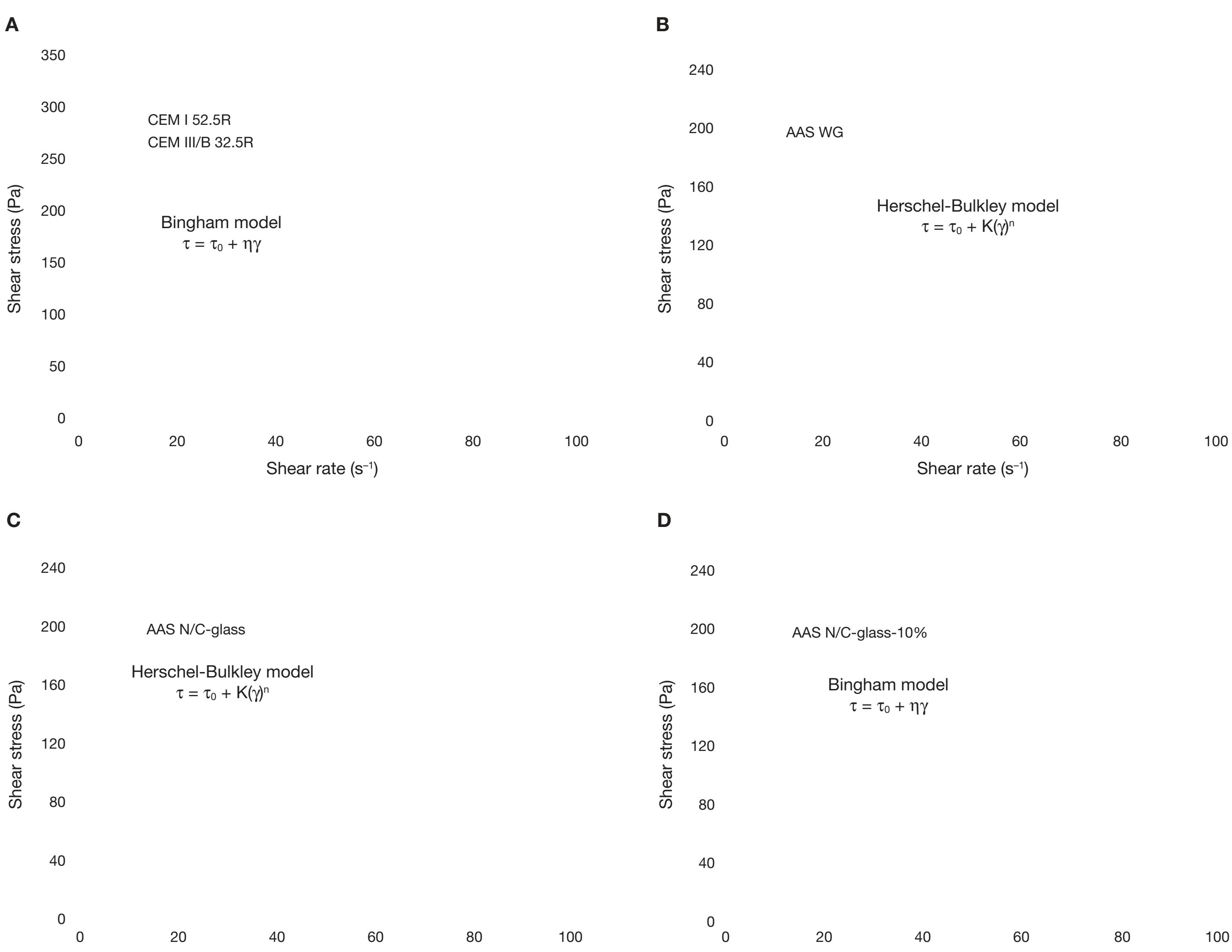

Fig. 9 – Pastes hysteresis cycles: A) CEM I 52.5R and CEM III/B 32.5R; B) AAS WG; C) AAS N/C-glass; D) AAS N/C-glass+10%.

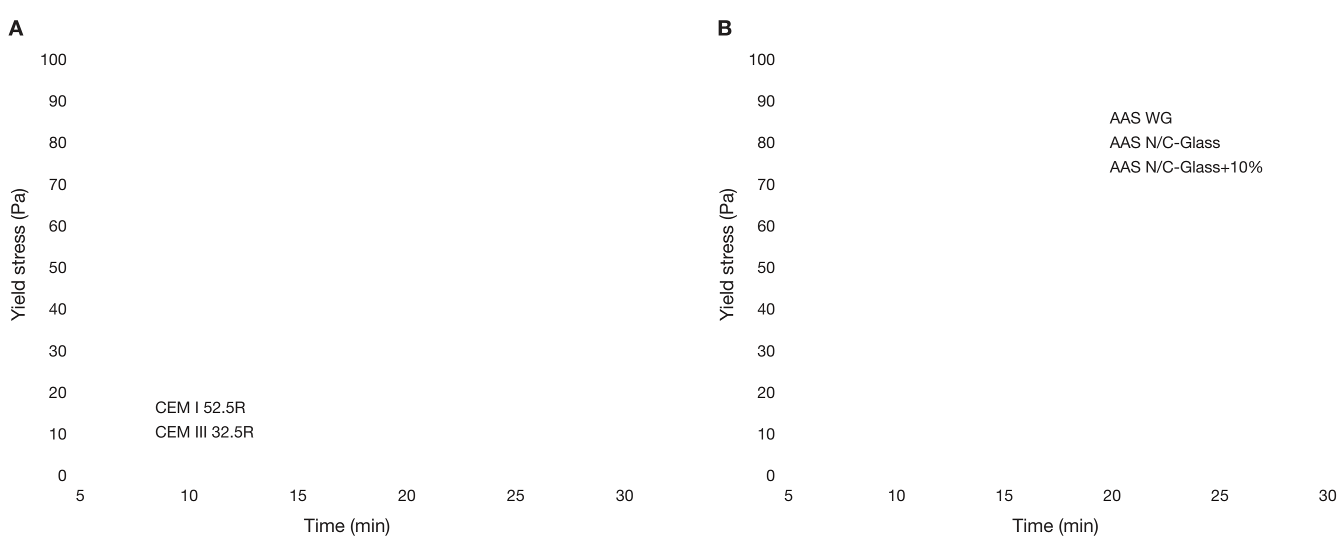

Fig. 10 – Yield stress in A) CEM I 52.5R and CEM III/B 32.5R; B) AAS WG, AAS N/C-Glass and AAS N/C-Glass+10%.

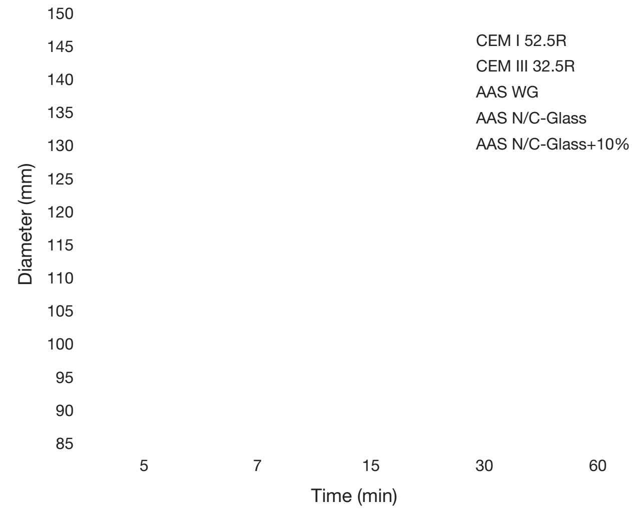

Fig. 11 – Minislump values for standard cements and AAS pastes with different activators.