In-situ hydraulic barriers formed from colloidal silica for nuclear decommissioning sites: ***Gelation behaviour of colloidal silica grout***

Christopher Wong
M Pedrotti, G El Mountassir, R Lunn
University of Strathclyde

Distinctive Theme 4 Meeting
23rd November 2015
University of Strathclyde, Glasgow

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DISTINCTIVE

OUTLINE

- Colloidal Silica Grout
- Gelation Behaviour
  - Experimental work
  - Analytical Model
- Grout Characterisation
  - Consolidation Behaviour
- Future Work

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DISTINCTIVE

COLLOIDAL SILICA GROUT

COLLOIDAL SILICA

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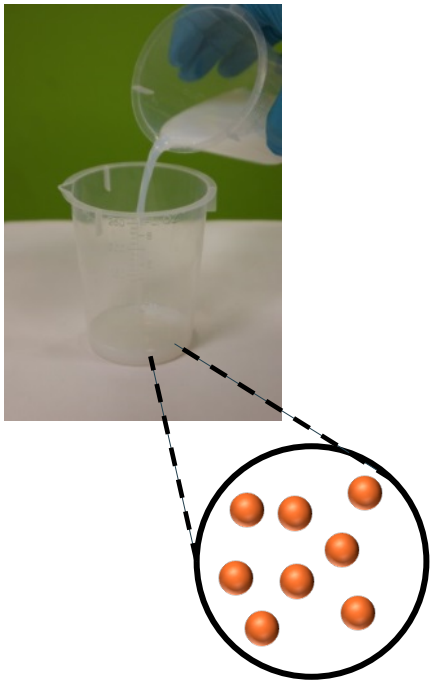
DISTINCTIVE

COLLOIDAL SILICA GROUT

COLLOIDAL SILICA



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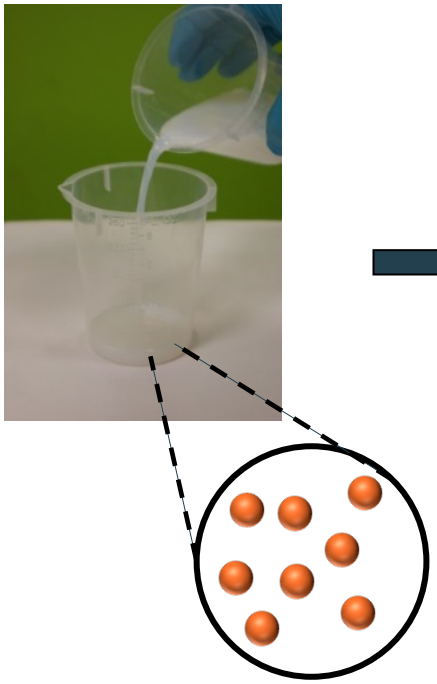
COLLOIDAL SILICA GROUT

COLLOIDAL SILICA



ACCELERATOR

$NaCl$, $CaCl_2$, KCl, etc

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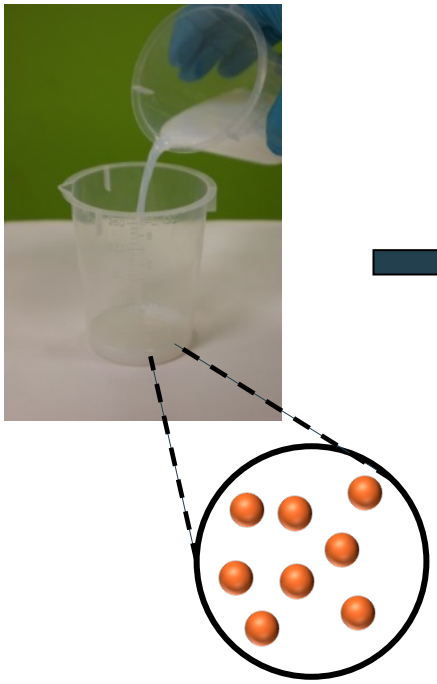
DISTINCTIVE

COLLOIDAL SILICA GROUT

COLLOIDAL SILICA



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SILICA GEL

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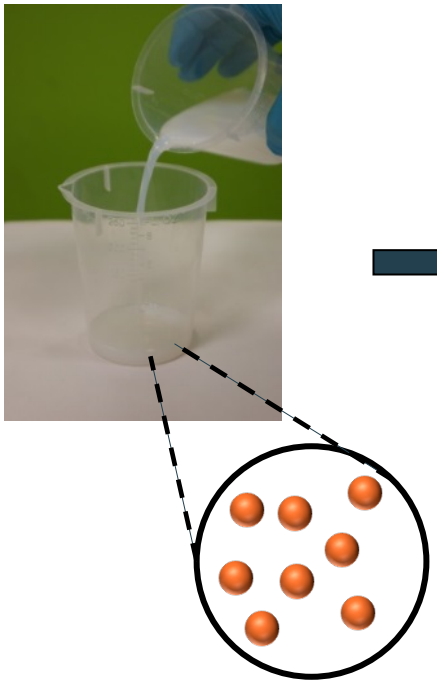
DISTINCTIVE

COLLOIDAL SILICA GROUT

COLLOIDAL SILICA



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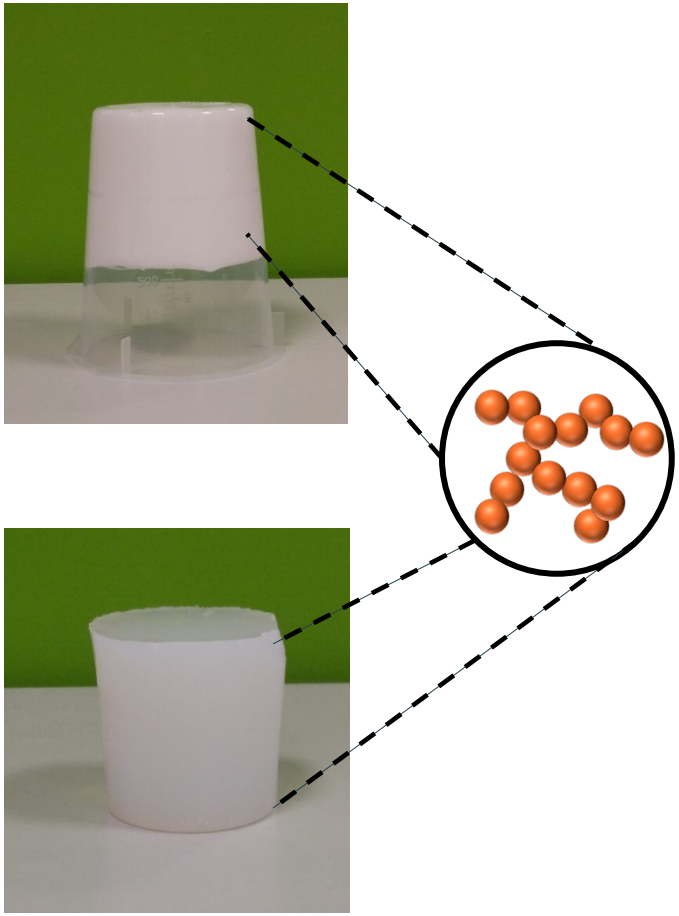

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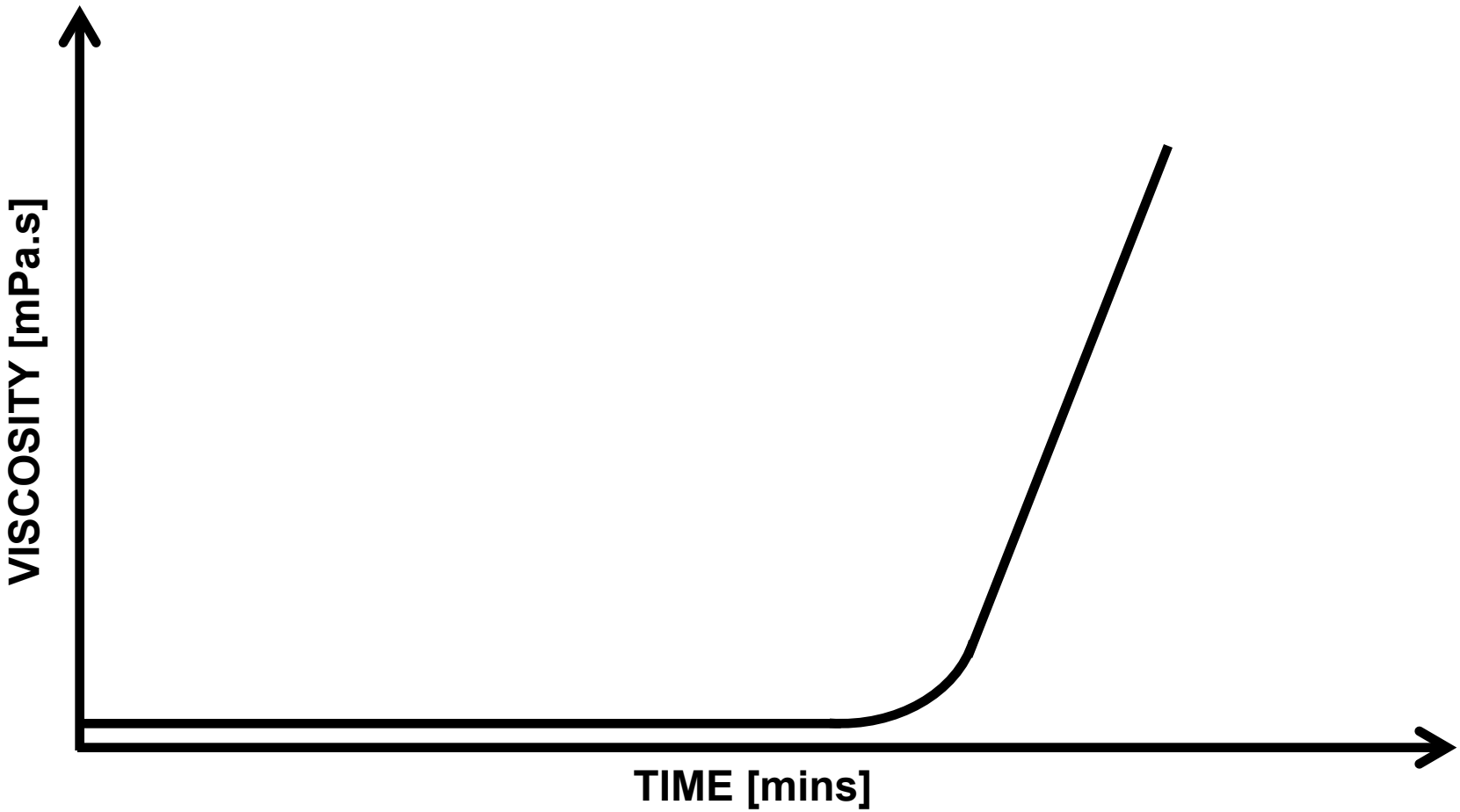
COLLOIDAL SILICA GELLING



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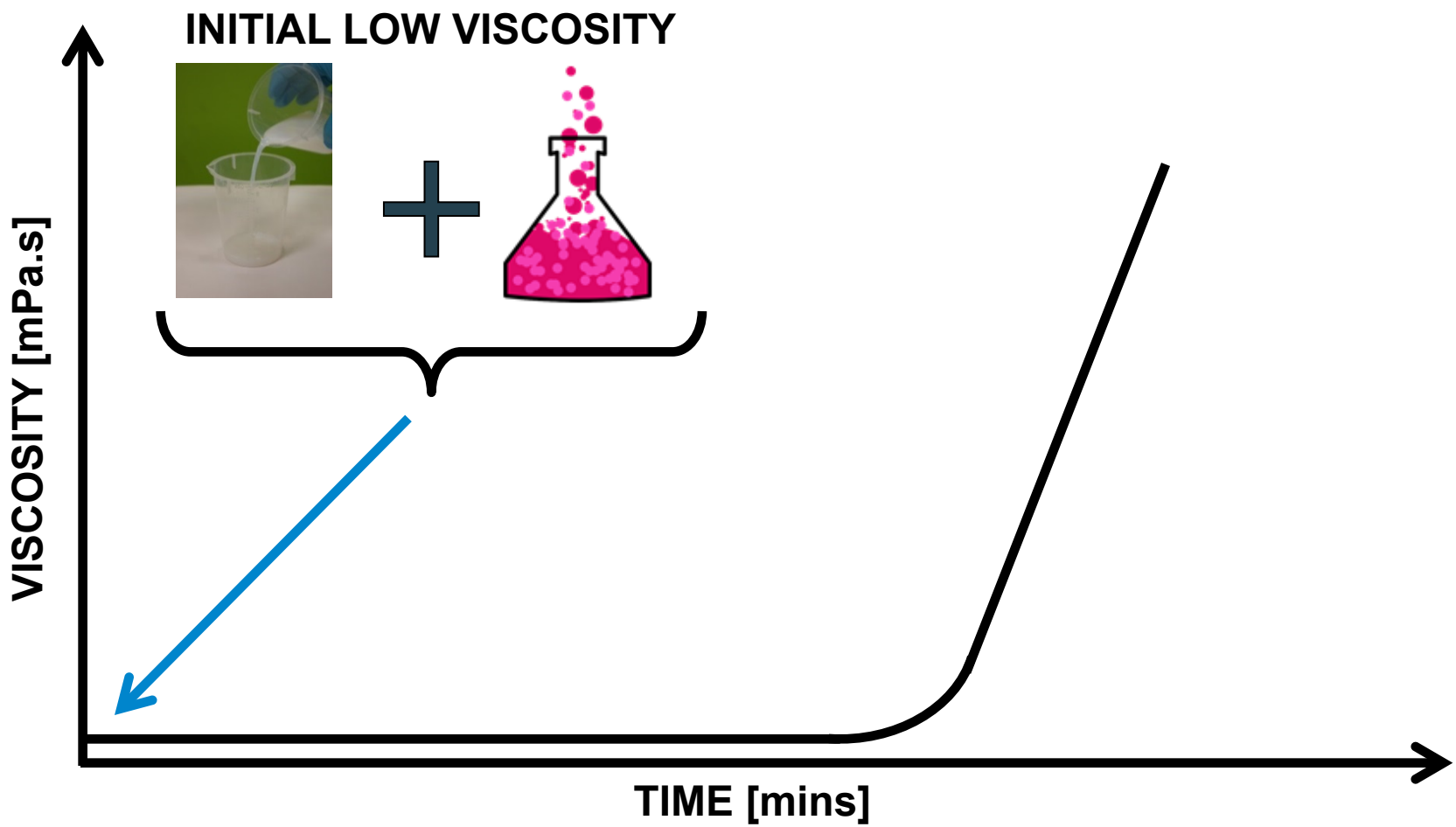
COLLOIDAL SILICA GELLING



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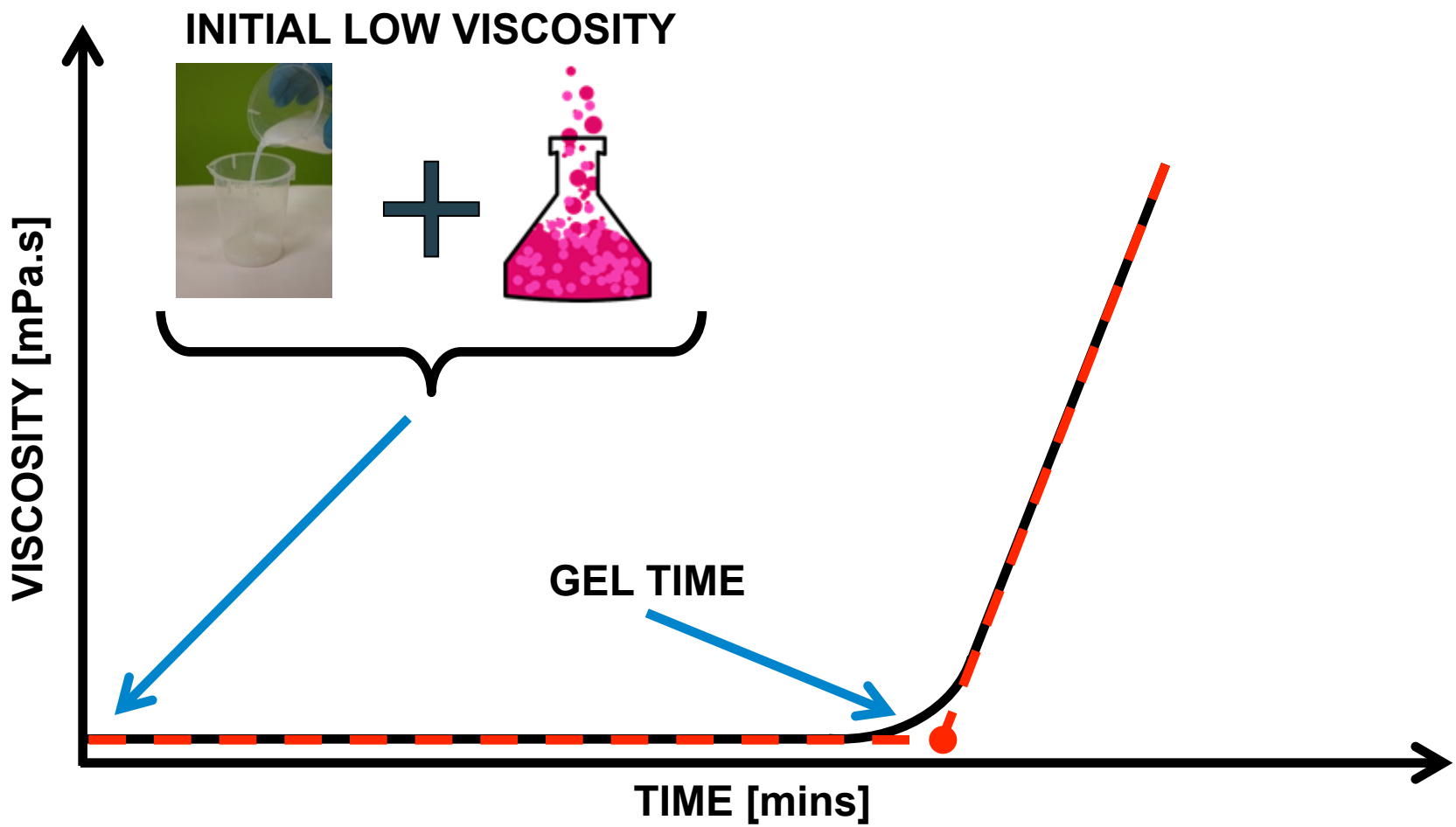

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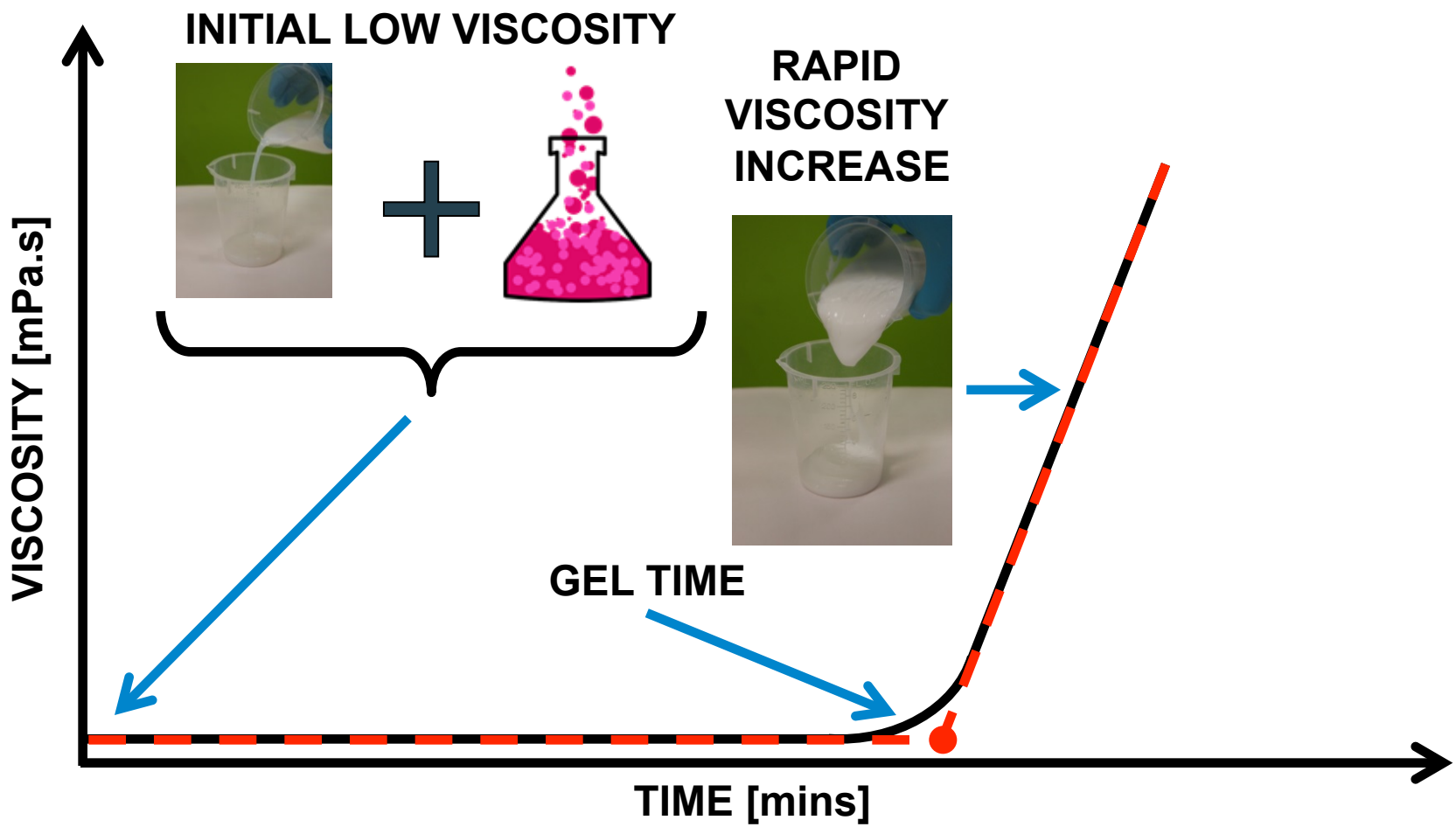
COLLOIDAL SILICA GELLING



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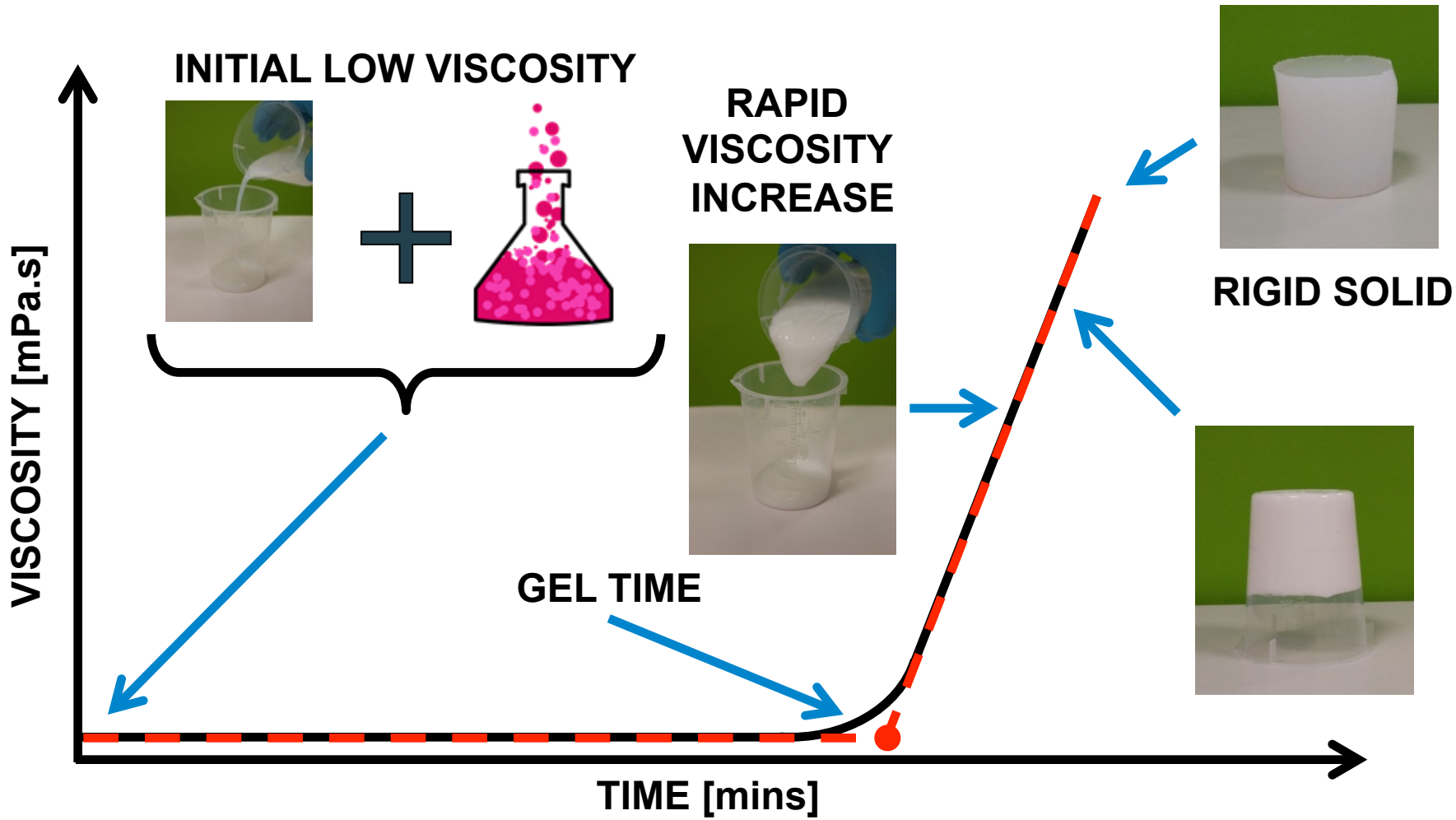
COLLOIDAL SILICA GELLING



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DISTINCTIVE

GEL TIME VARIABLES

Colloidal silica gel time depends on:

SELECTED

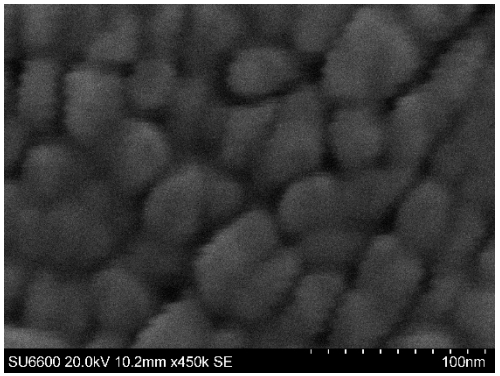
- Silica particle concentration (silica/water by weight)
- Silica particle size

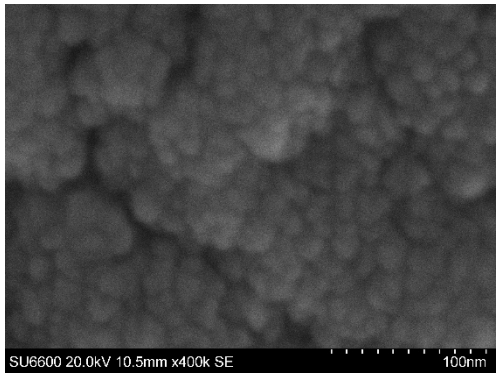
SITE SPECIFIC

- pH
- Electrolyte concentration
- Type of electrolyte
- Temperature

COLLOIDAL SILICA PROPERTIES

- Meyco MP320
- Silica particle content (by mass) 40%
- Particle size
- Variation between batches
- Measurement procedures to determine silica parameters
  - Bulk density
  - Particle size





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DISTINCTIVE

GEL TIME VARIABLES – EXPERIMENTAL WORK CONDUCTED

Accelerator conditions

- pH range: 3 – 9
- Electrolyte conc.: 2.0M to 0.5M NaCl
- Cation valency: NaCl, $CaCl_2$
- Molar mass: KCl
- Silica particle conc. (by mass): 37% and 40%
- Temperature range: 12°C – 35°C

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DISTINCTIVE

GEL TIME VARIABLES - pH

Electrolyte concentration	[2M NaCl]
Particle size	[17nm]
Particle concentration	[40% w/w]

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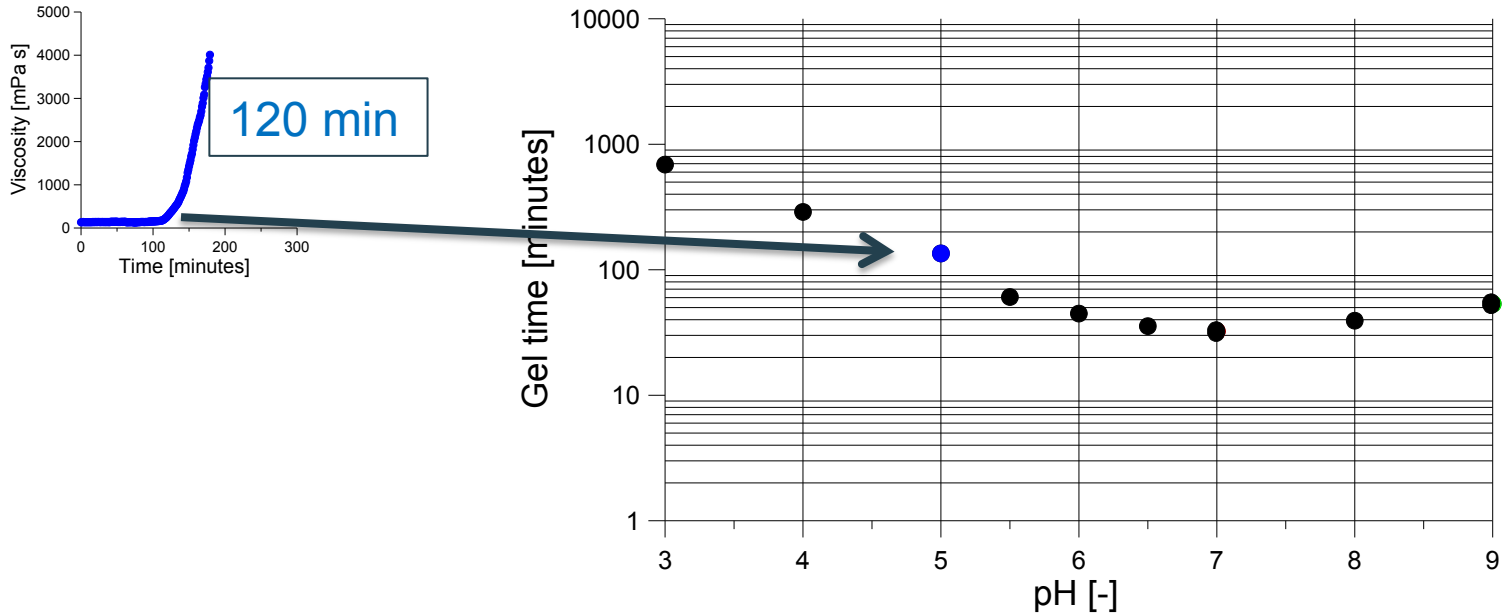
DISTINCTIVE

GEL TIME VARIABLES - pH

Electrolyte concentration	**[2M NaCl]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

pH 5



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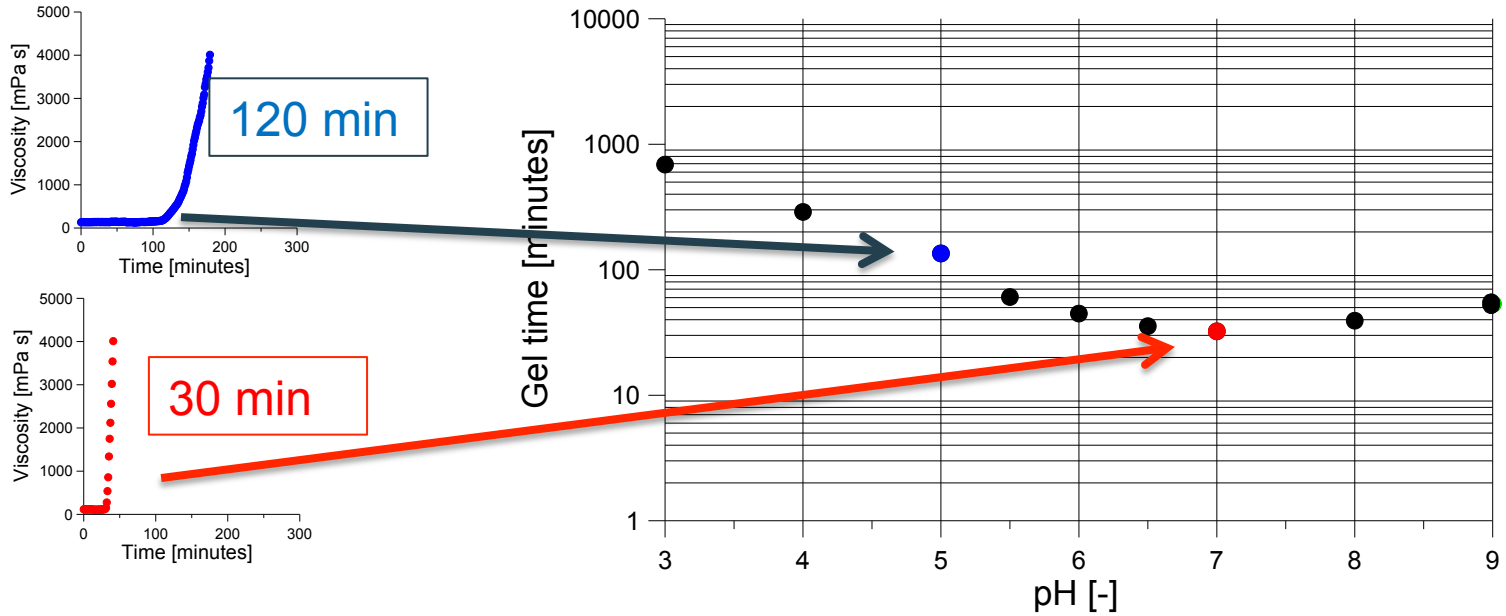
DISTINCTIVE

GEL TIME VARIABLES - pH

Electrolyte concentration	**[2M NaCl]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

pH 5

pH 7



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DISTINCTIVE

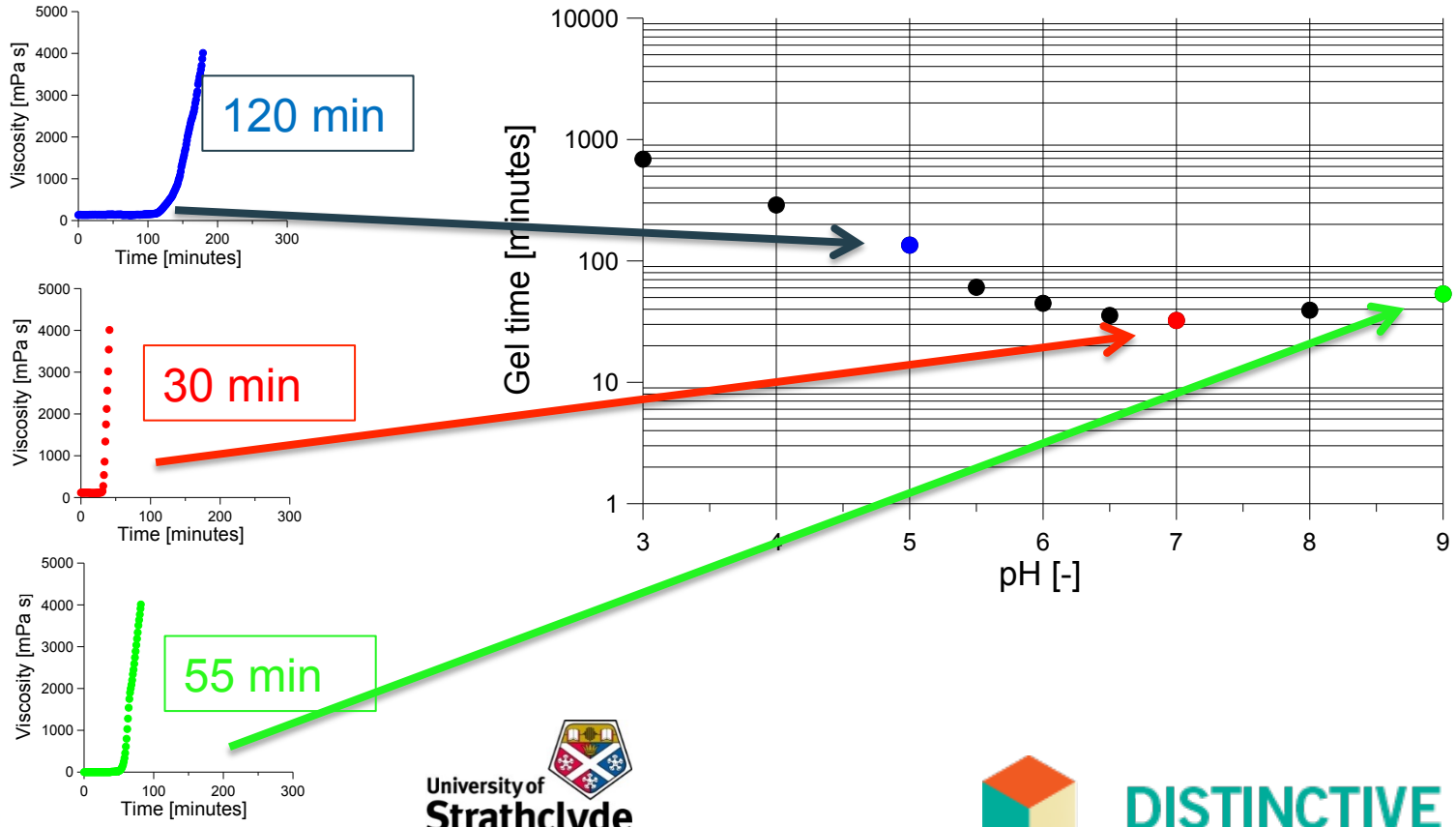
GEL TIME VARIABLES - pH

Electrolyte concentration	**[2M NaCl]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

pH 5

pH 7

pH 9



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DISTINCTIVE

GEL TIME VARIABLES - pH

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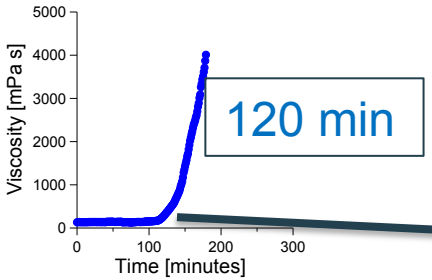
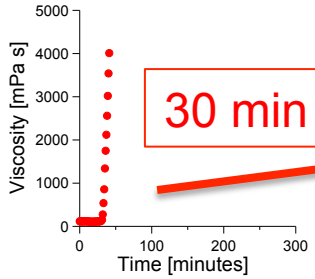
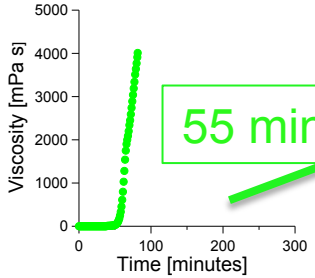
pH 5

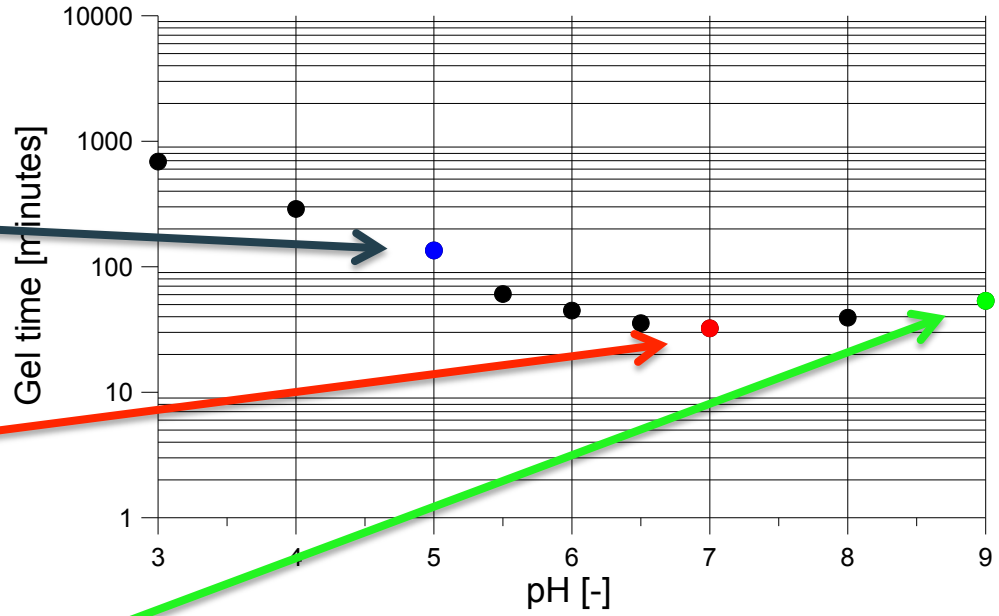


pH 7



pH 9





NON-MONOTONIC

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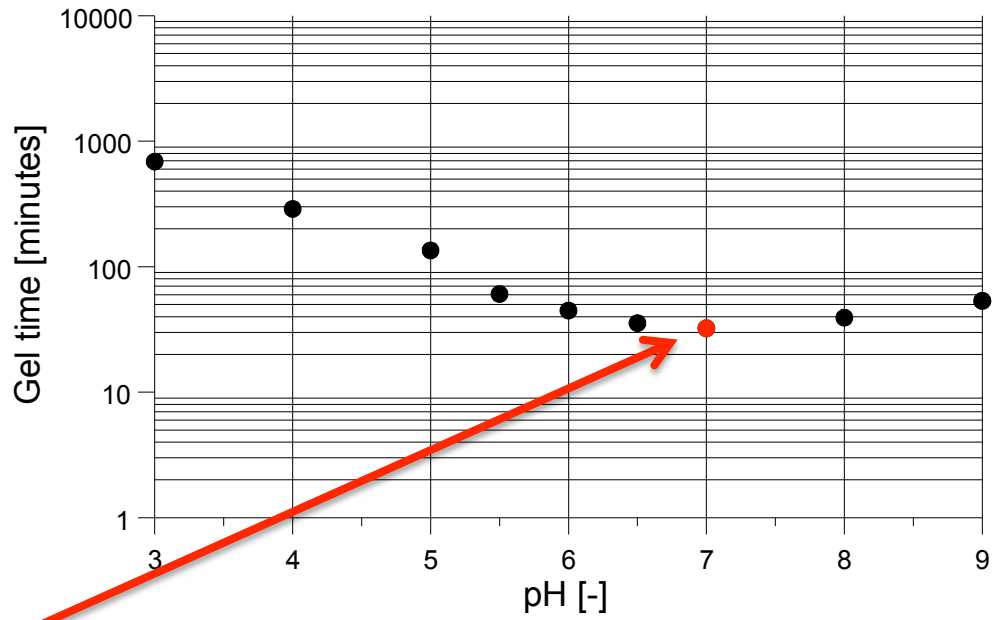
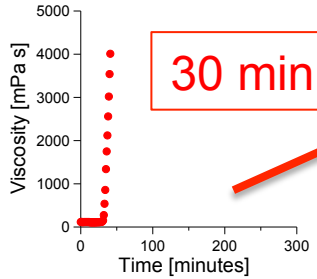
DISTINCTIVE

GEL TIME VARIABLES - ELECTROLYTE CONCENTRATION

pH	**[7]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**



2.0M of NaCl



30 min

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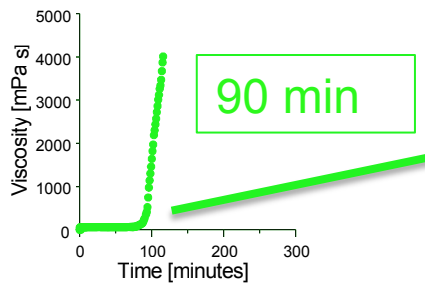
DISTINCTIVE

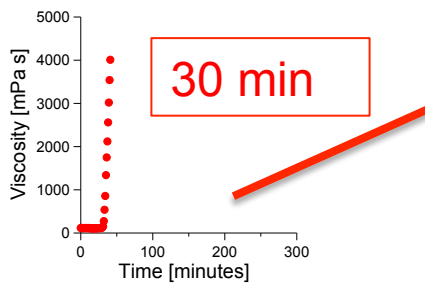
GEL TIME VARIABLES - ELECTROLYTE CONCENTRATION

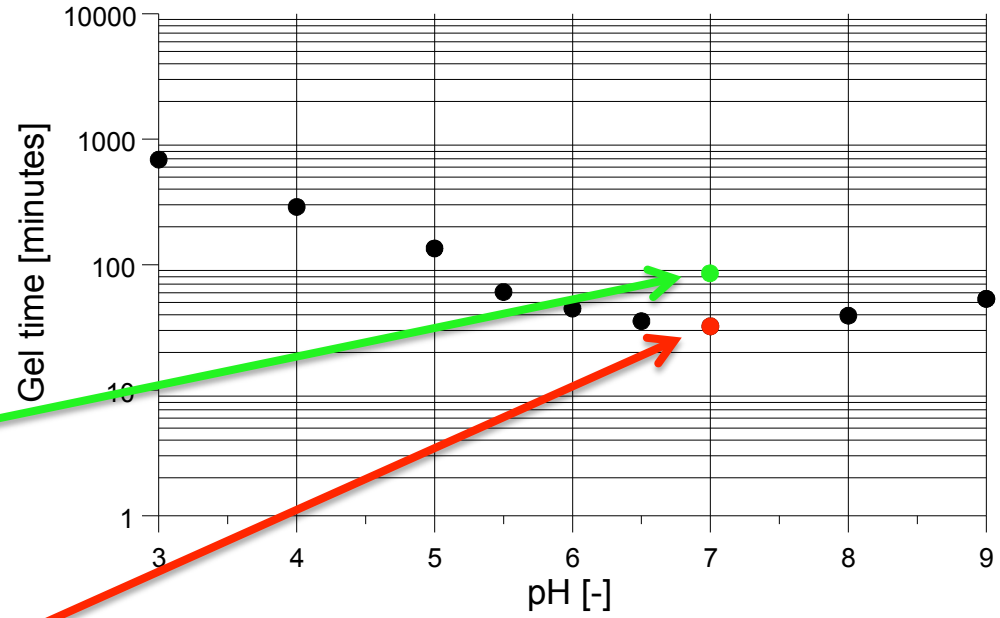
pH	**[7]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

1.4M of NaCl



2.0M of NaCl





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DISTINCTIVE

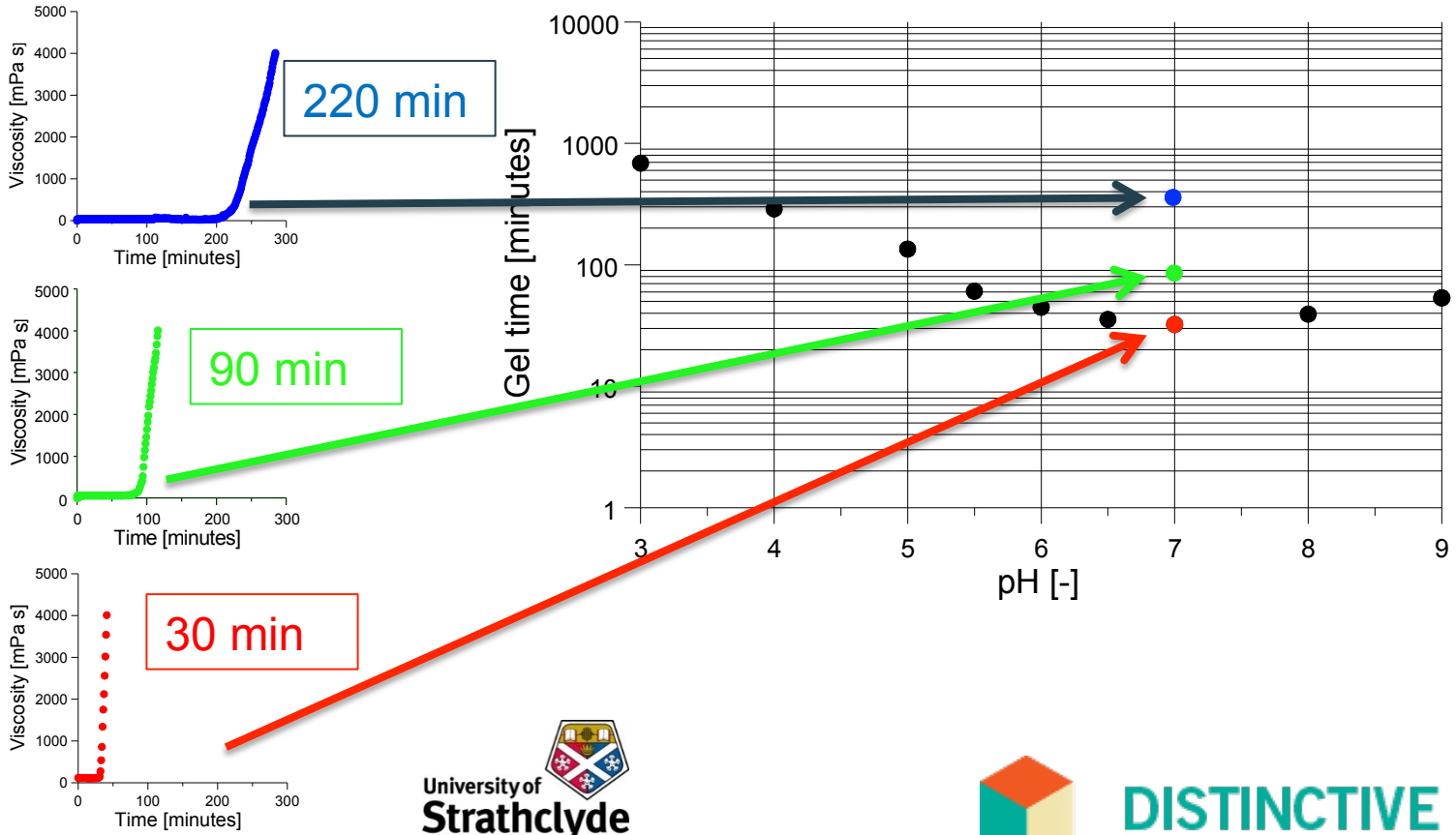
GEL TIME VARIABLES - ELECTROLYTE CONCENTRATION

pH	**[7]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

1.0M of NaCl

1.4M of NaCl

2.0M of NaCl



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DISTINCTIVE

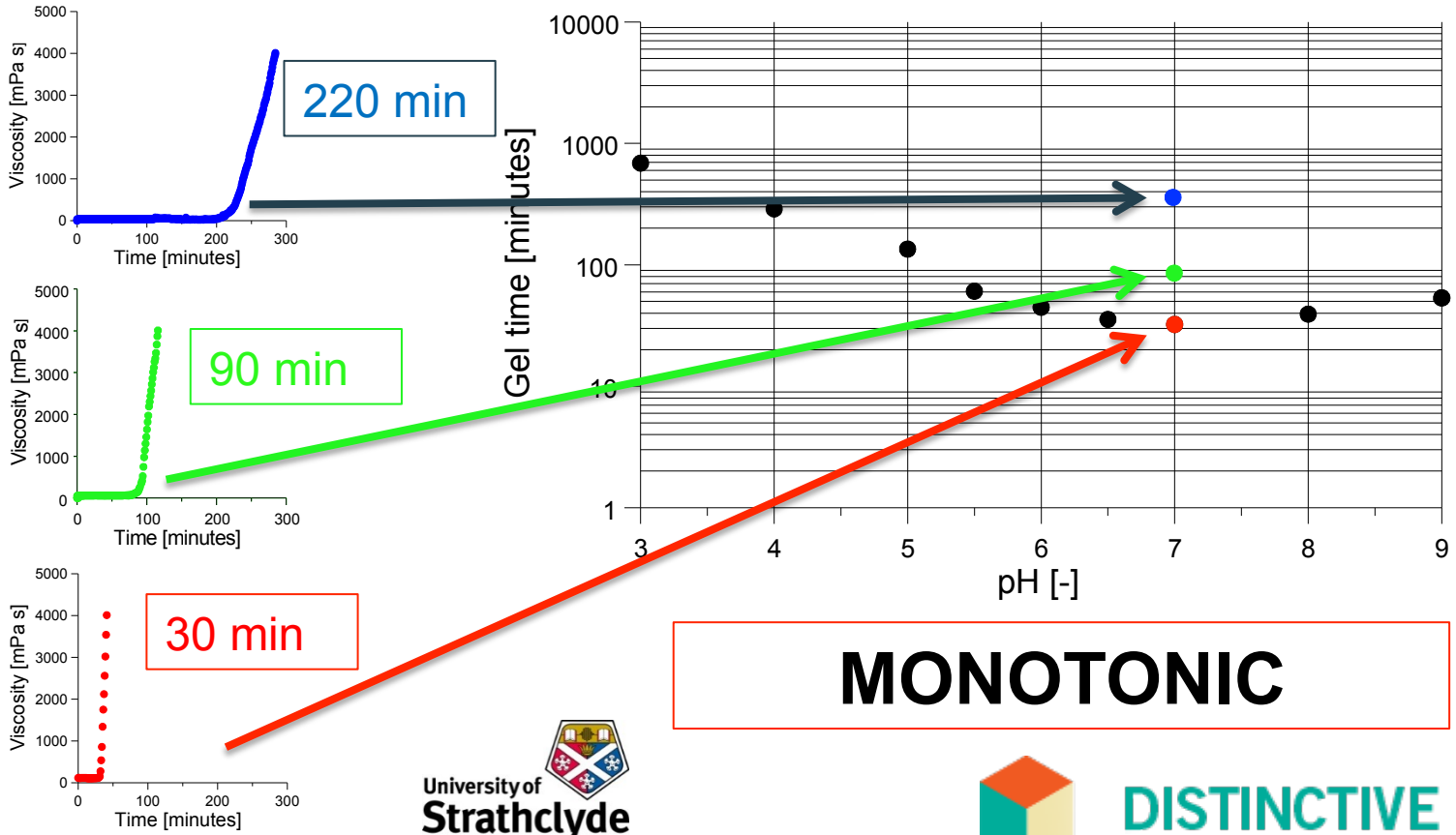
GEL TIME VARIABLES - ELECTROLYTE CONCENTRATION

pH	**[7]**
Particle size	**[17nm]**
Particle concentration	**[40% w/w]**

1.0M of NaCl

1.4M of NaCl

2.0M of NaCl



MONOTONIC

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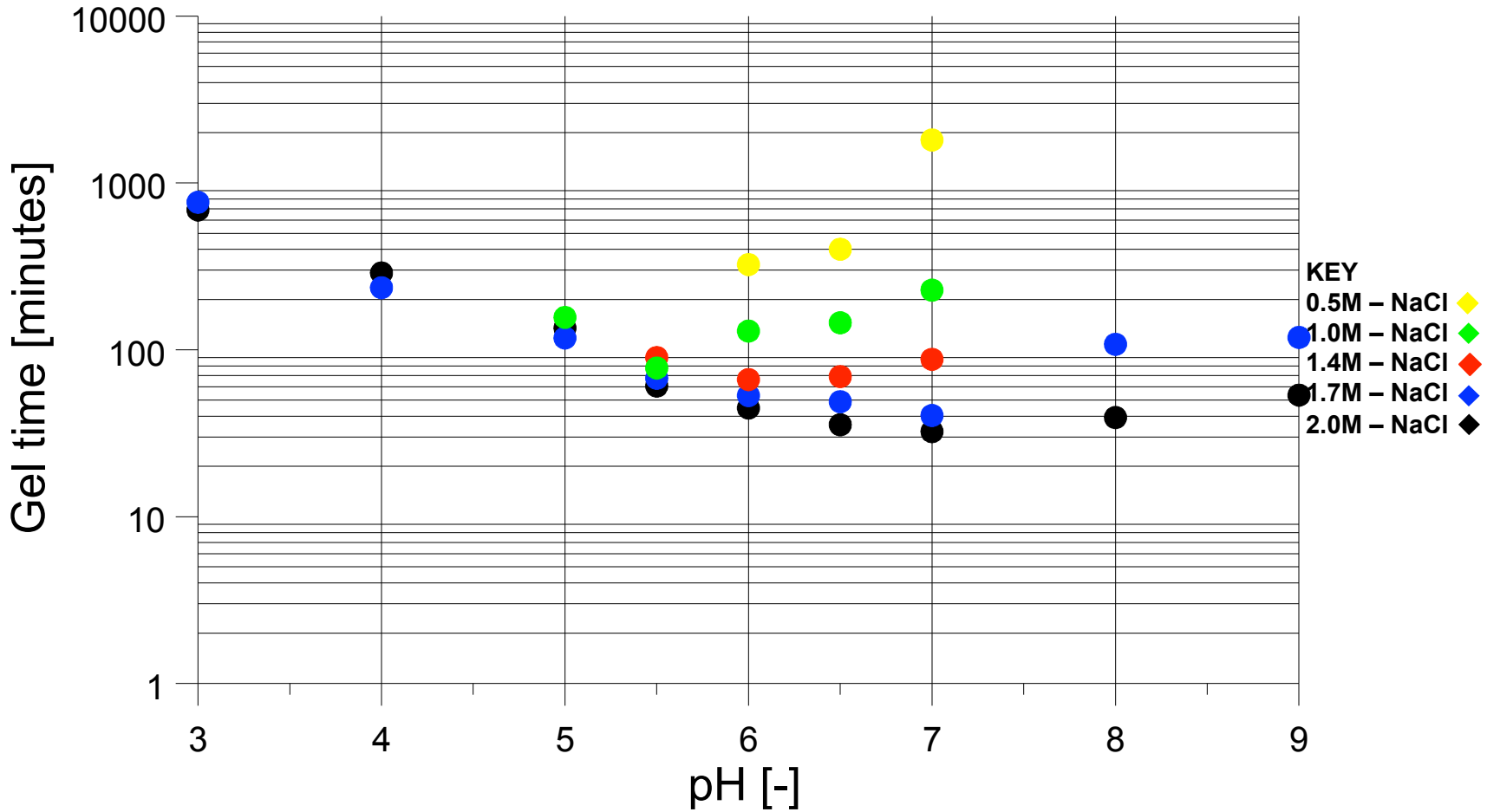
DISTINCTIVE

GEL TIME VARIABLES – ELECTROLYTE CONCENTRATION & pH



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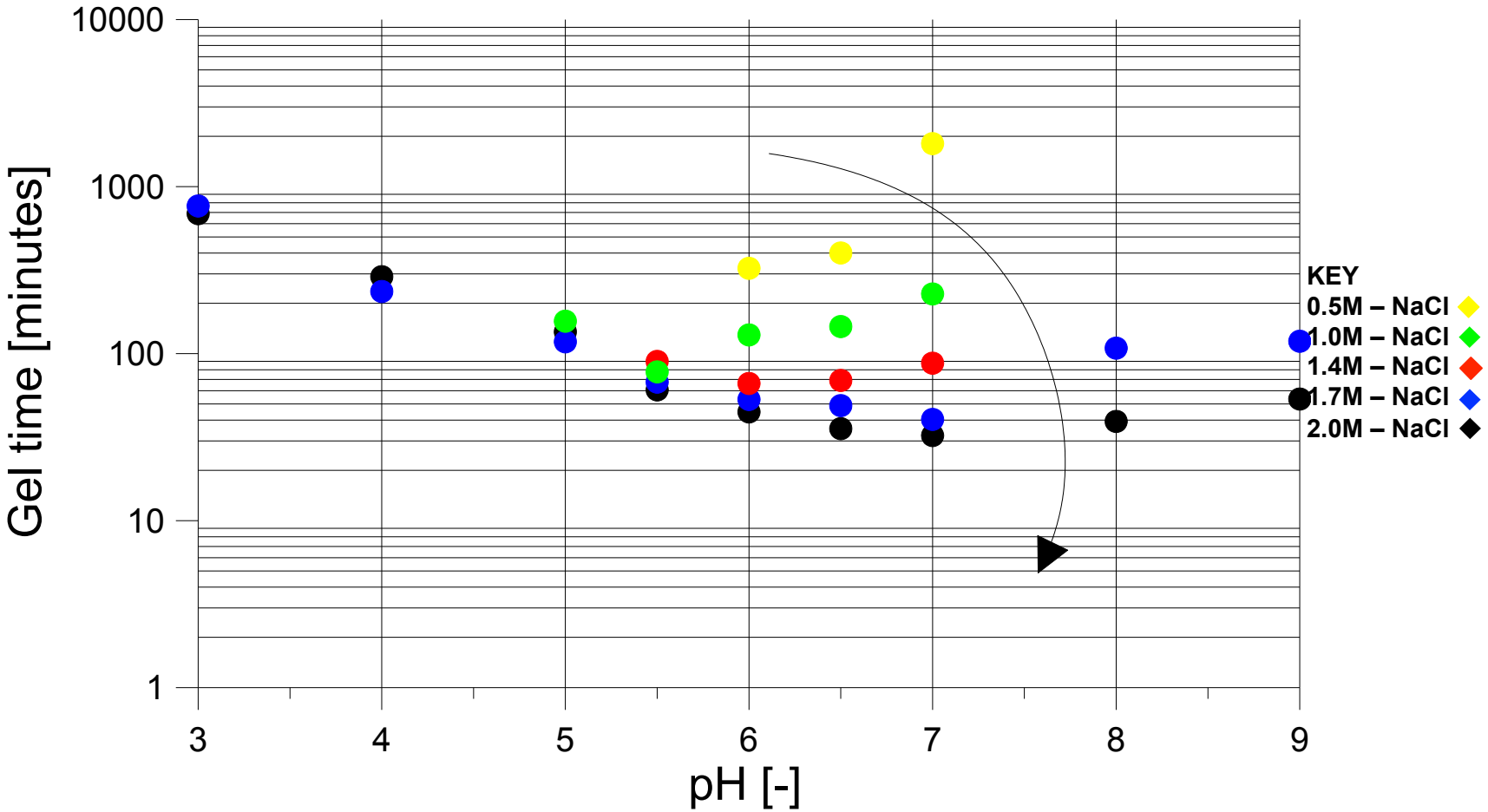
DISTINCTIVE

GEL TIME VARIABLES – ELECTROLYTE CONCENTRATION & pH



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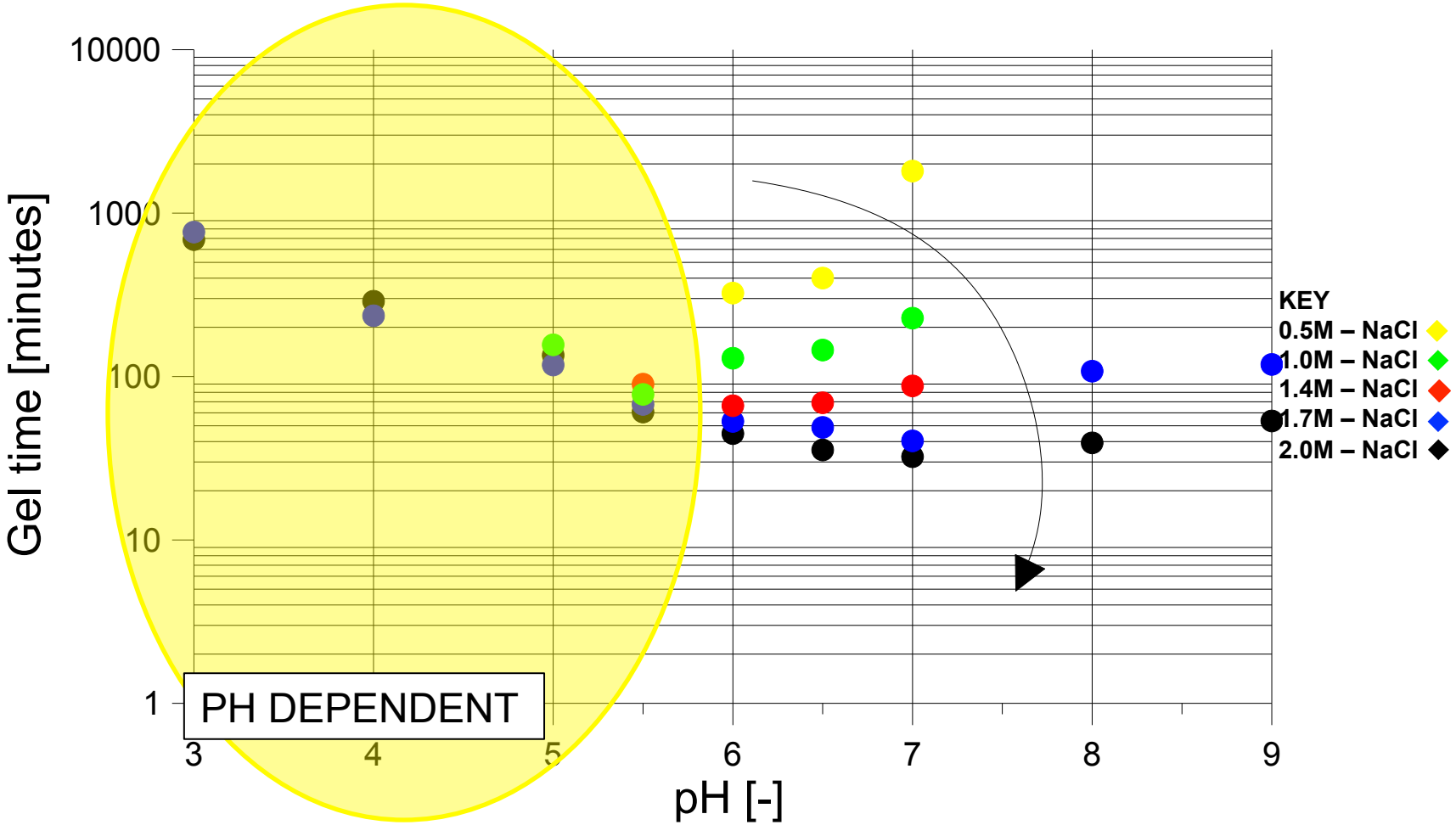
DISTINCTIVE

GEL TIME VARIABLES – ELECTROLYTE CONCENTRATION & pH



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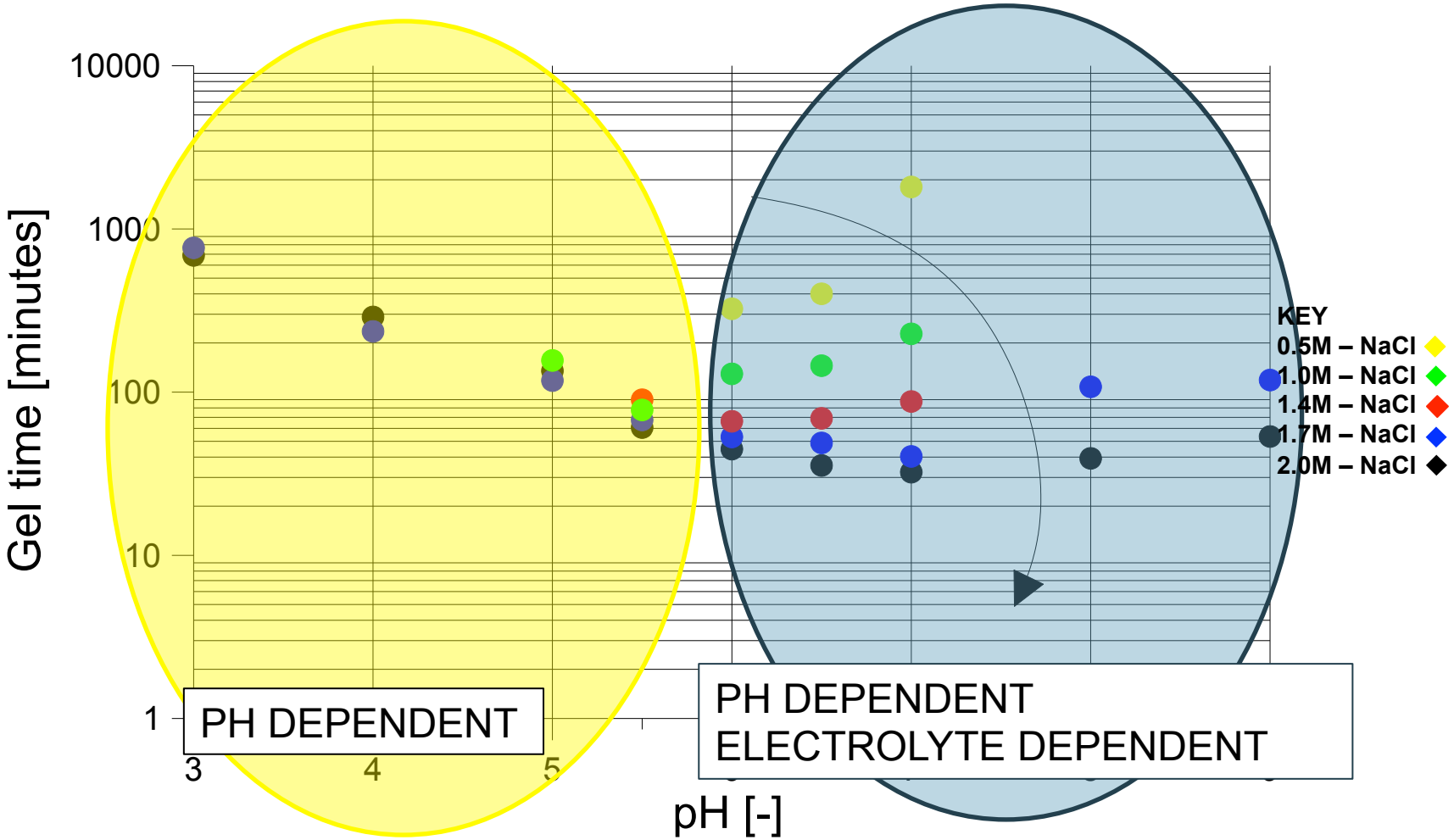
DISTINCTIVE

GEL TIME VARIABLES – ELECTROLYTE CONCENTRATION & pH



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ANALYTICAL MODEL

- Effect of pH
- Effect of the electrolytes
- Effect of the total specific surface area (particle size a

- Gel time prediction
- Viscosity prediction

AN ANALYTICAL MODEL FOR THE GELLING OF SILICA GROUT USING IN-SITU GROUNDWATER. (Pedrotti, M; Wong, C; El Mountassir, G; Lunn, R J. 2015) [paper submitted to Environmental Science & Technology]

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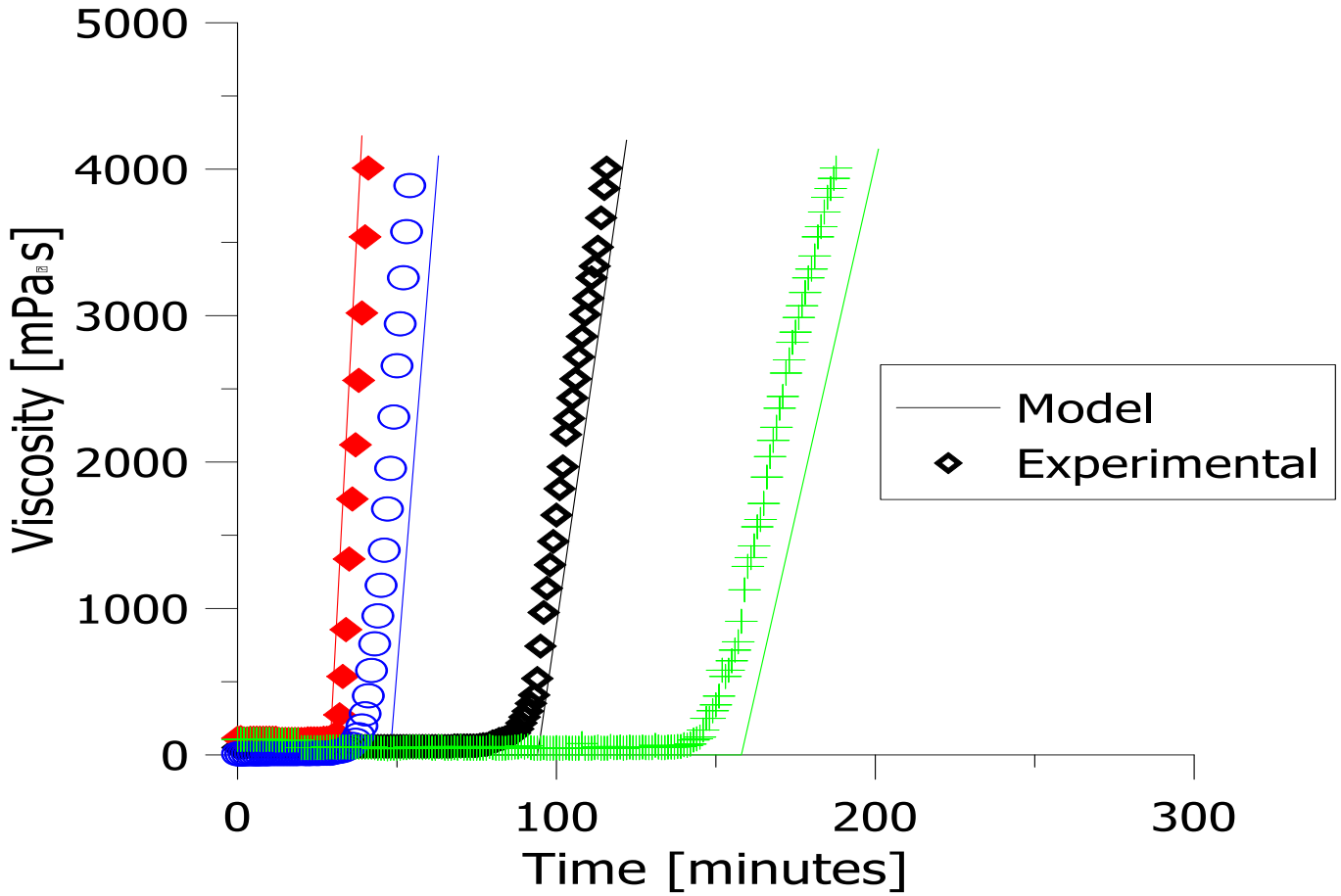
MODEL CALIBRATION – VISCOSITY EVOLUTION



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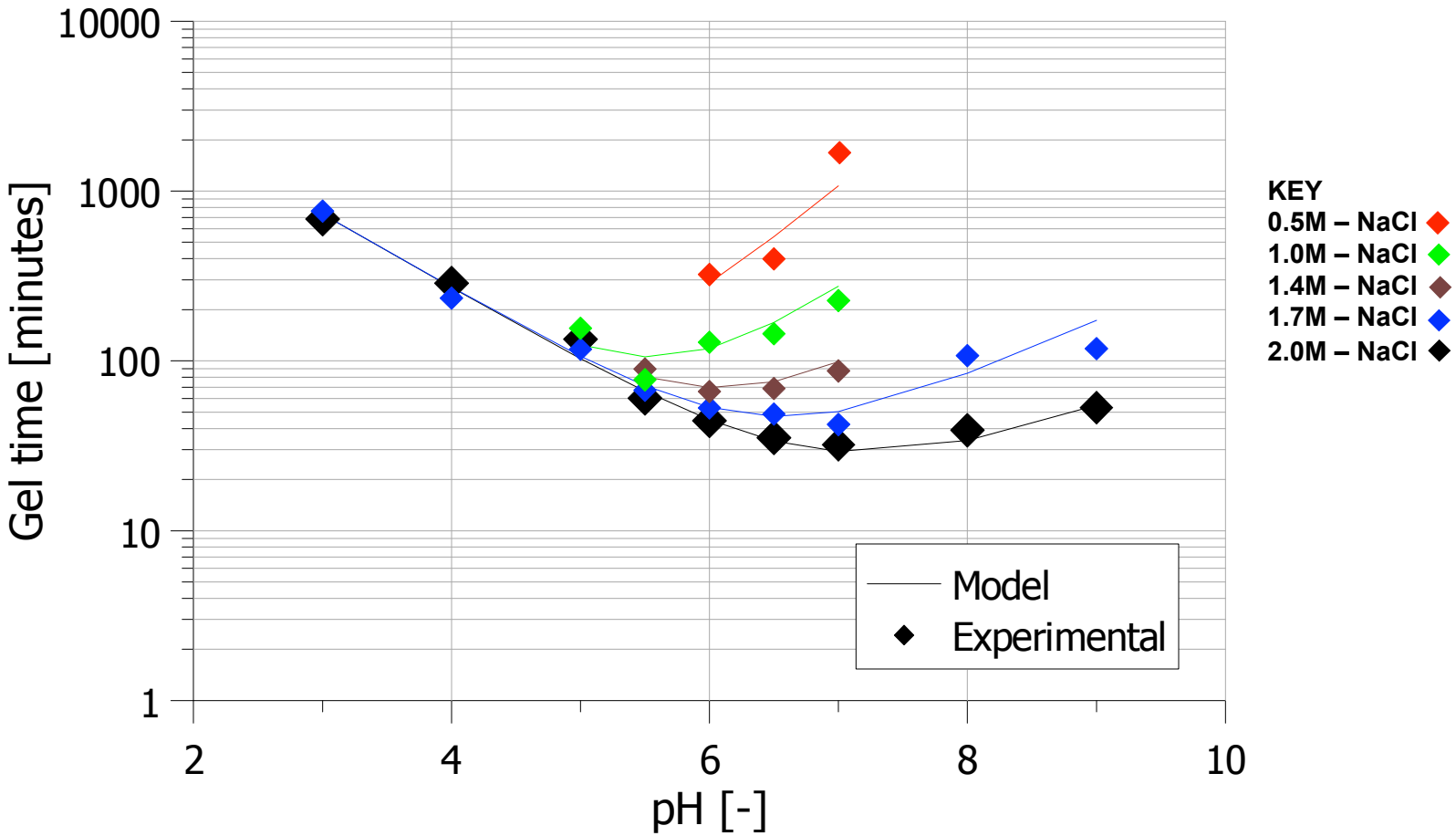
MODEL CALIBRATION – GEL TIME



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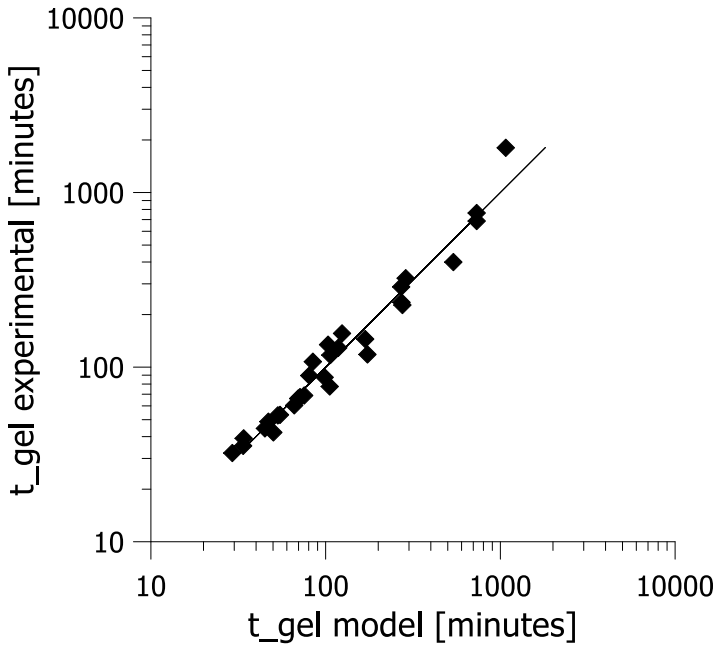
MODEL CALIBRATION - FITTING CURVE



Standard deviation of less than 20 minutes over a maximum experimental gel time of 1809 minutes

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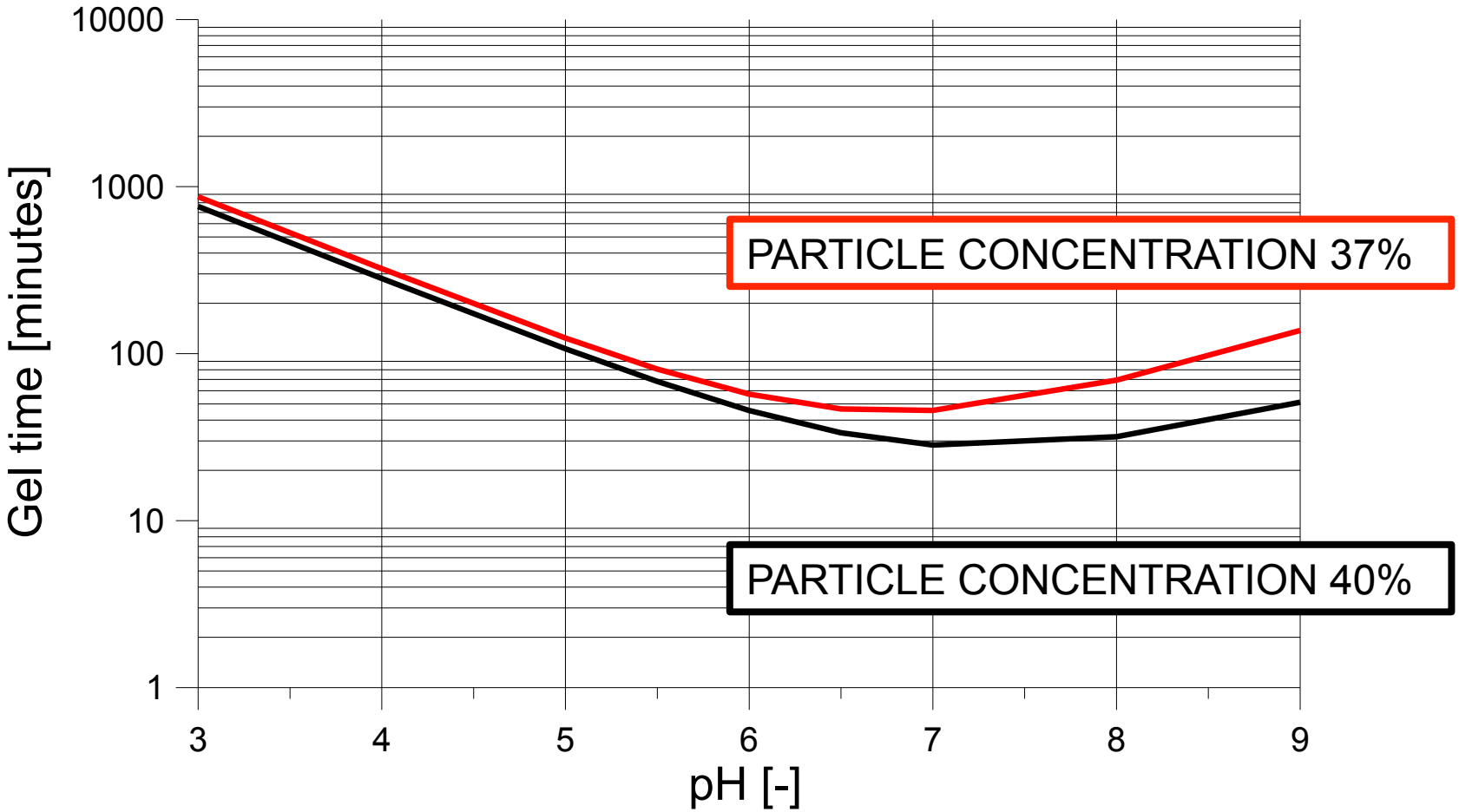
MODEL VALIDATION – DIFFERENT PARTICLE CONCENTRATION



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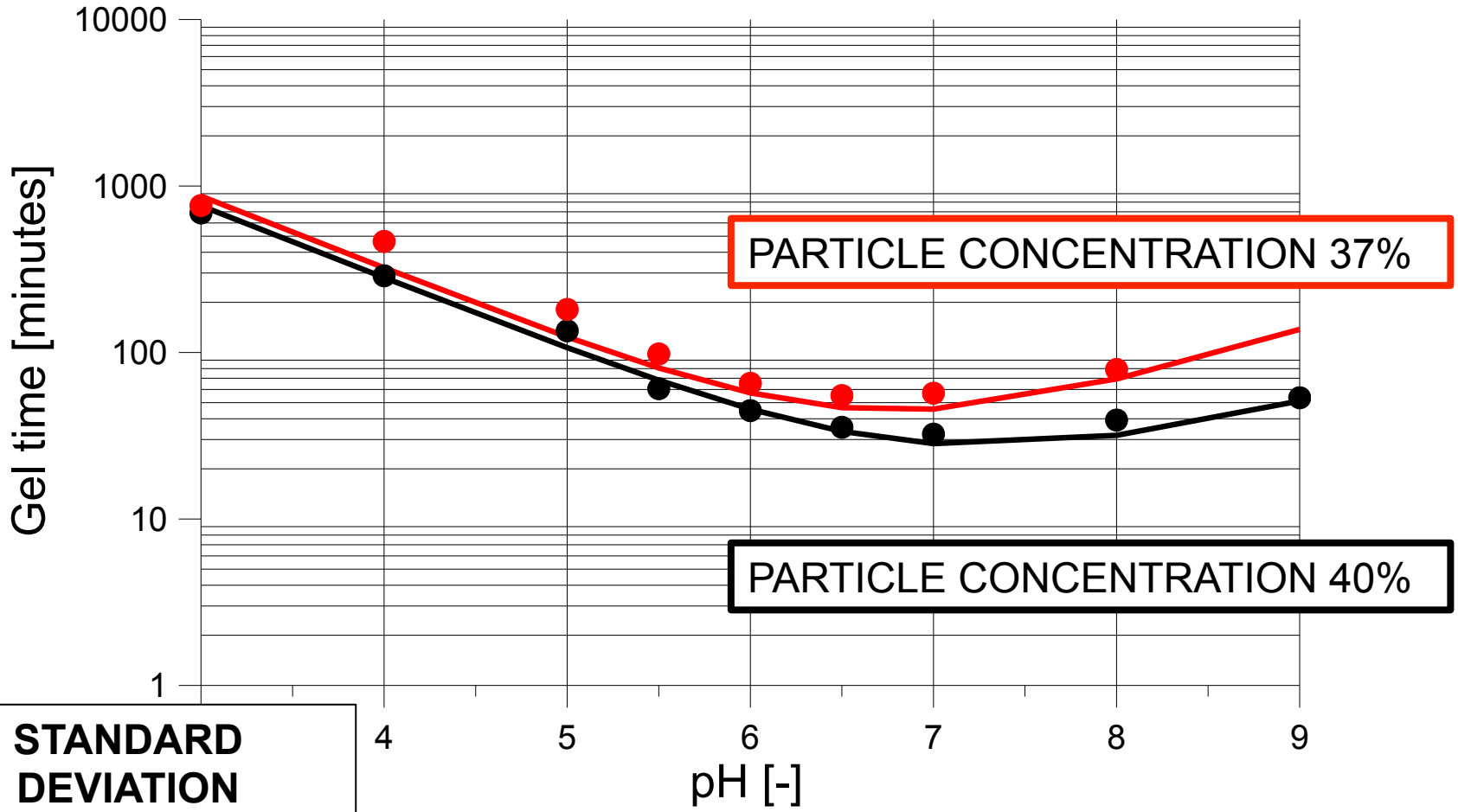
MODEL VALIDATION – DIFFERENT PARTICLE CONCENTRATION



STANDARD DEVIATION 12 MINUTES

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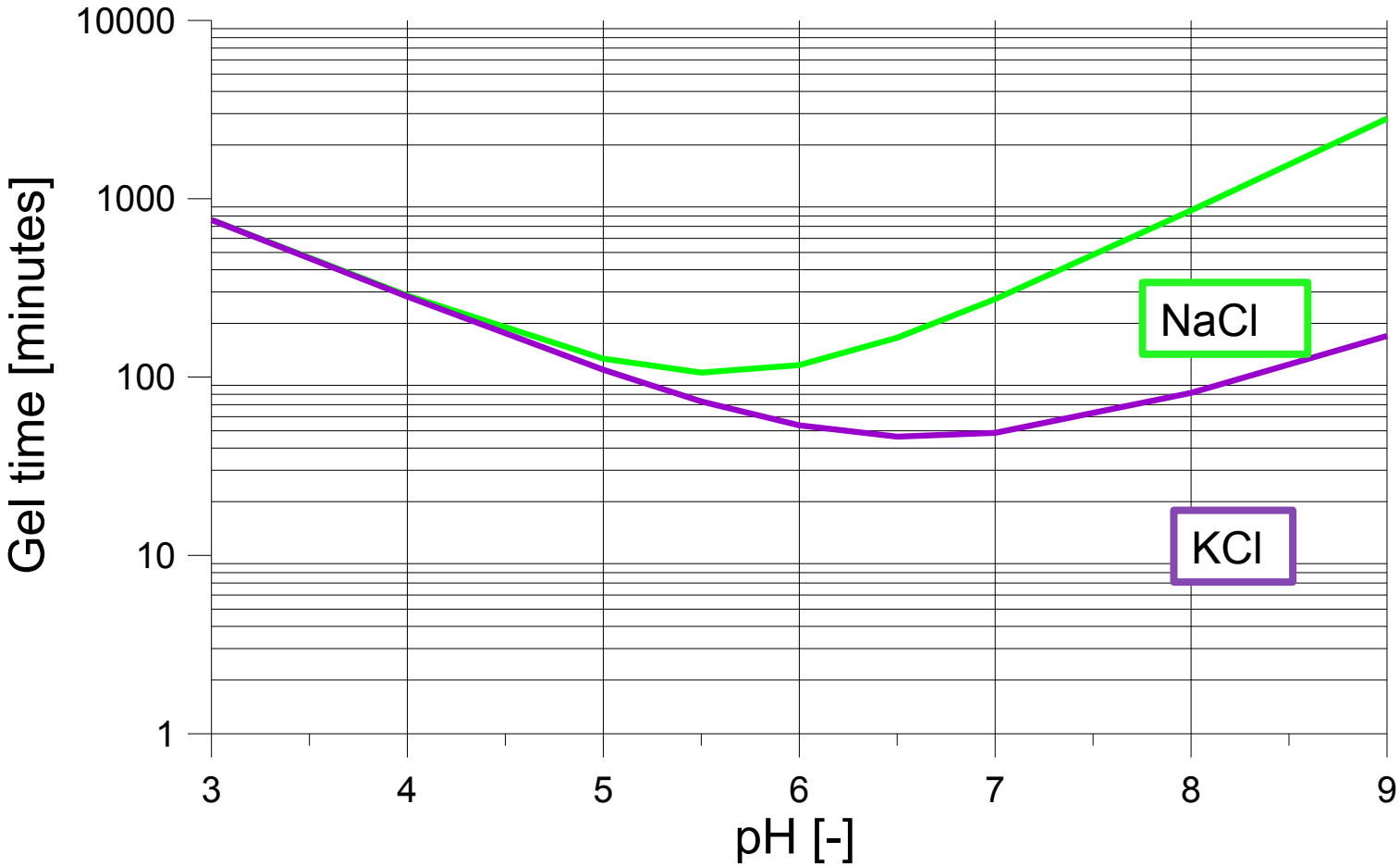
DISTINCTIVE

MODEL VALIDATION – MONOVALENT CATIONS



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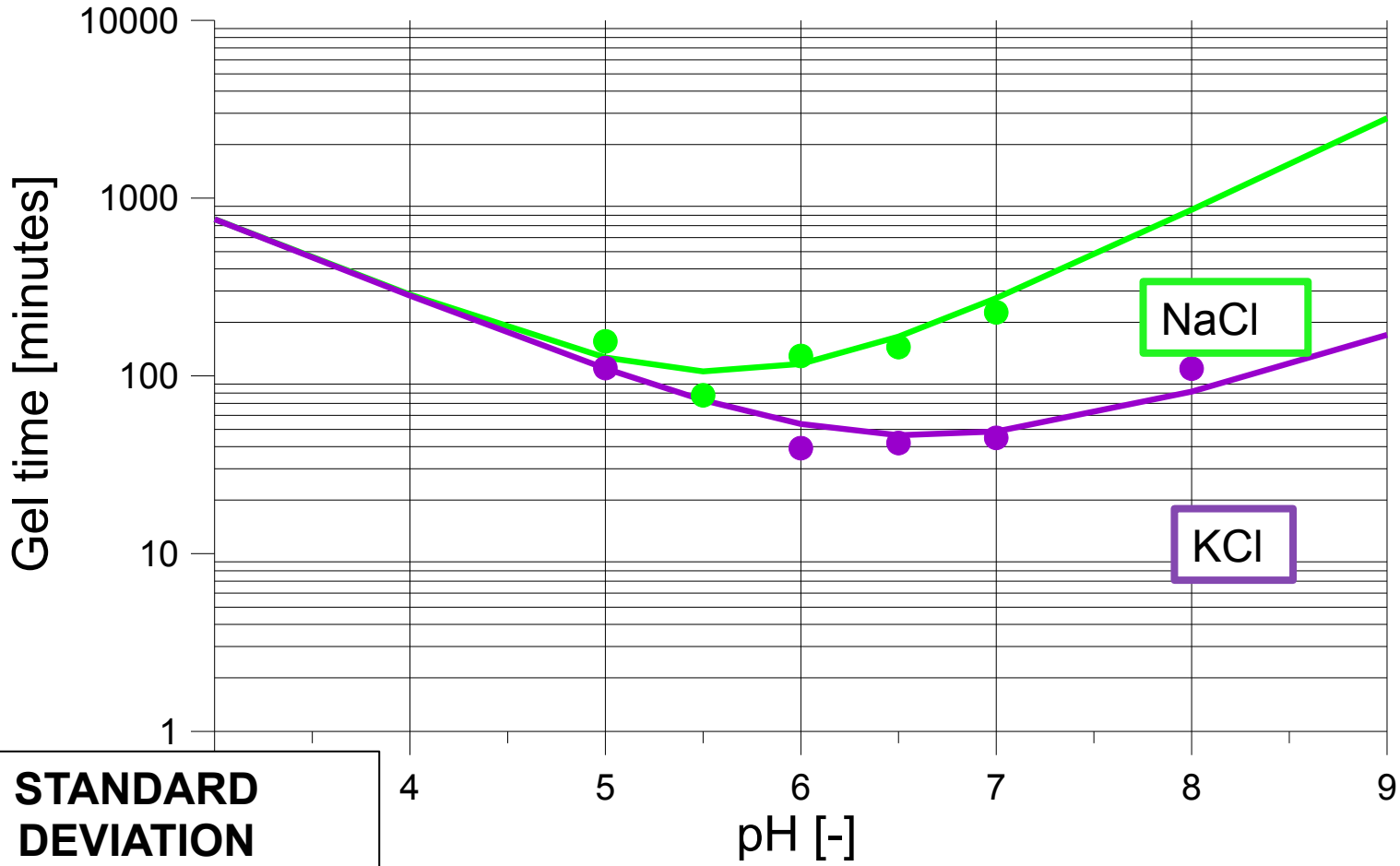
MODEL VALIDATION – MONOVALENT CATIONS



STANDARD DEVIATION 7 MINUTES

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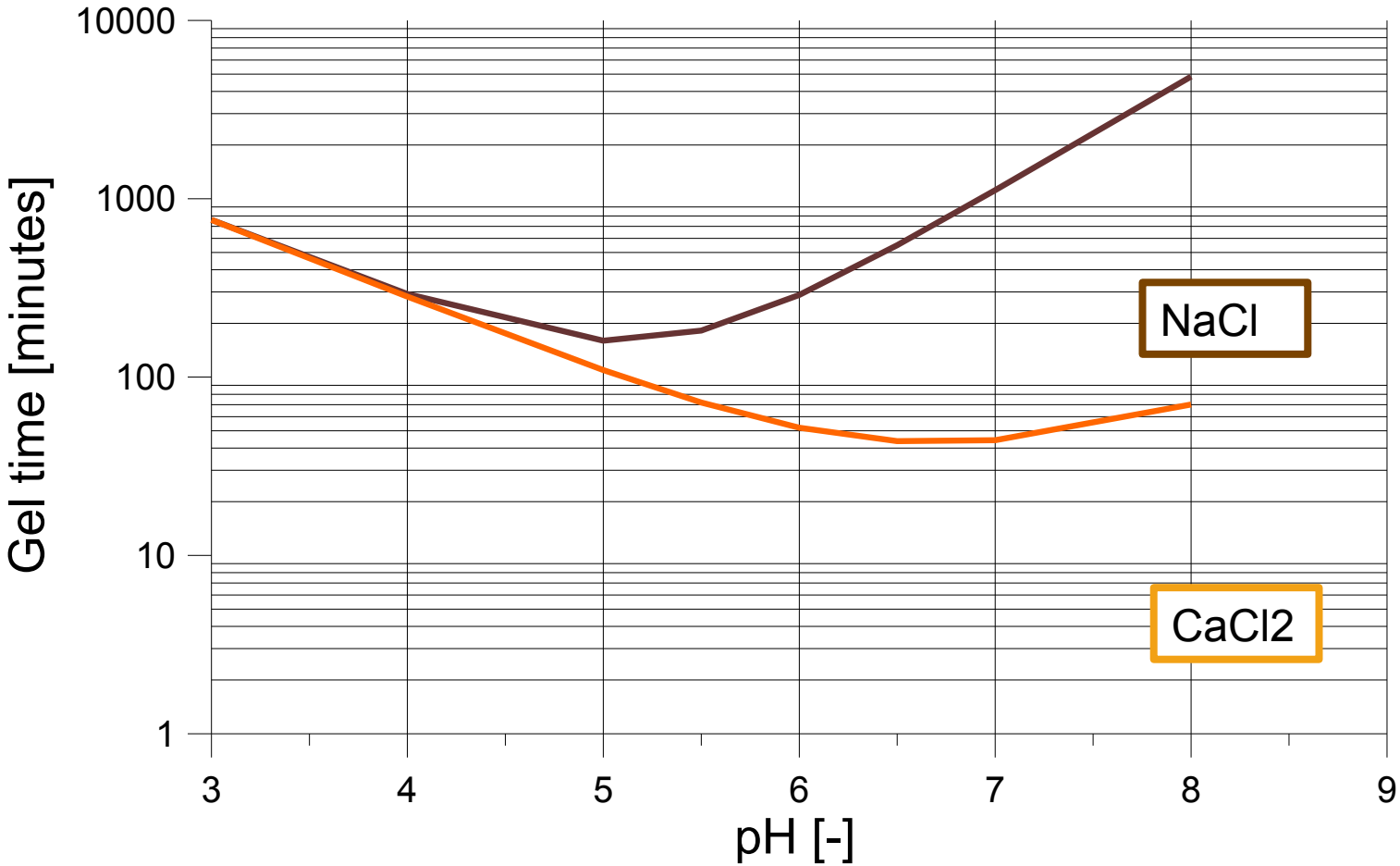
DISTINCTIVE

MODEL VALIDATION – DIVALENT CATIONS



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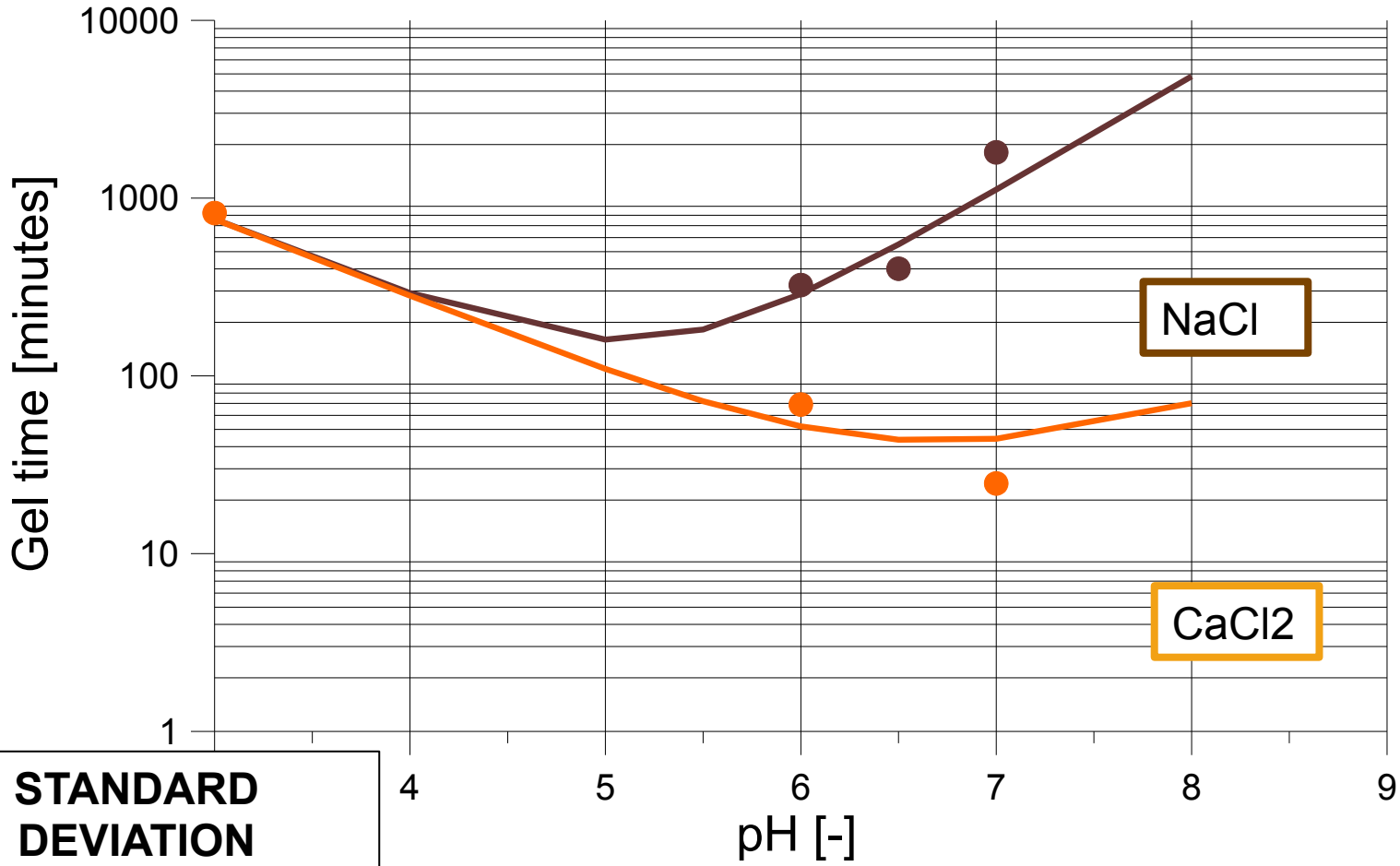
MODEL VALIDATION – DIVALENT CATIONS



STANDARD DEVIATION 22 MINUTES

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DISTINCTIVE

GROUT CHARACTERISATION

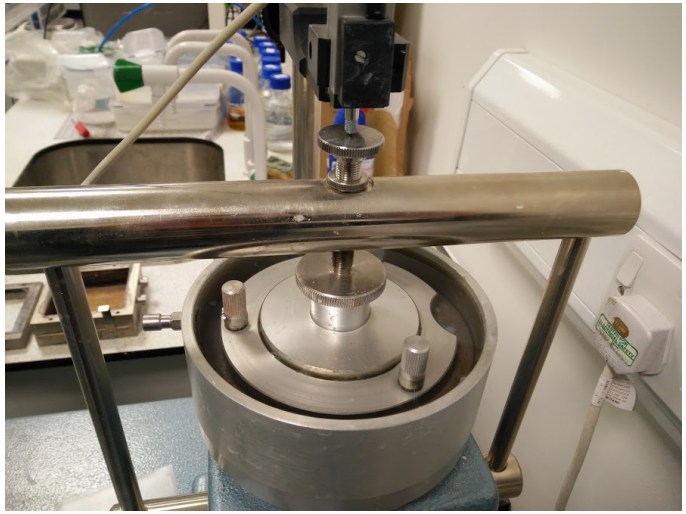
Investigate hydro-mechanical behaviour:

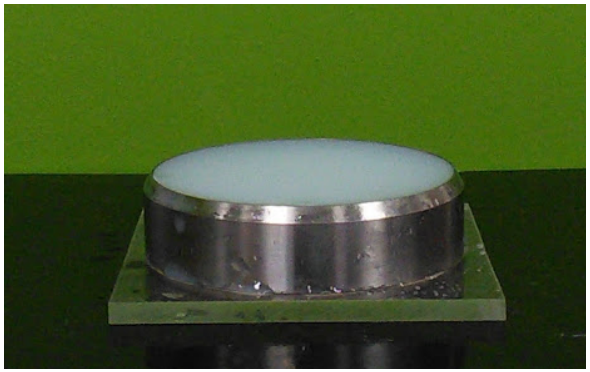
1. Stress-strain behaviour (consolidation, shearing) – influence of curing conditions, influence of curing time
2. Water retention behaviour
3. Hydraulic conductivity
4. Grout microstructure (pore size distribution, specific surface area, porosity)

GROUT CHARACTERISATION – CONSOLIDATION BEHAVIOUR

Consolidation testing oedometer

- Sample cured in cell rings
- Diameter: 75mm, H: 20mm
- Tested after 4 days of samples left in distilled water.





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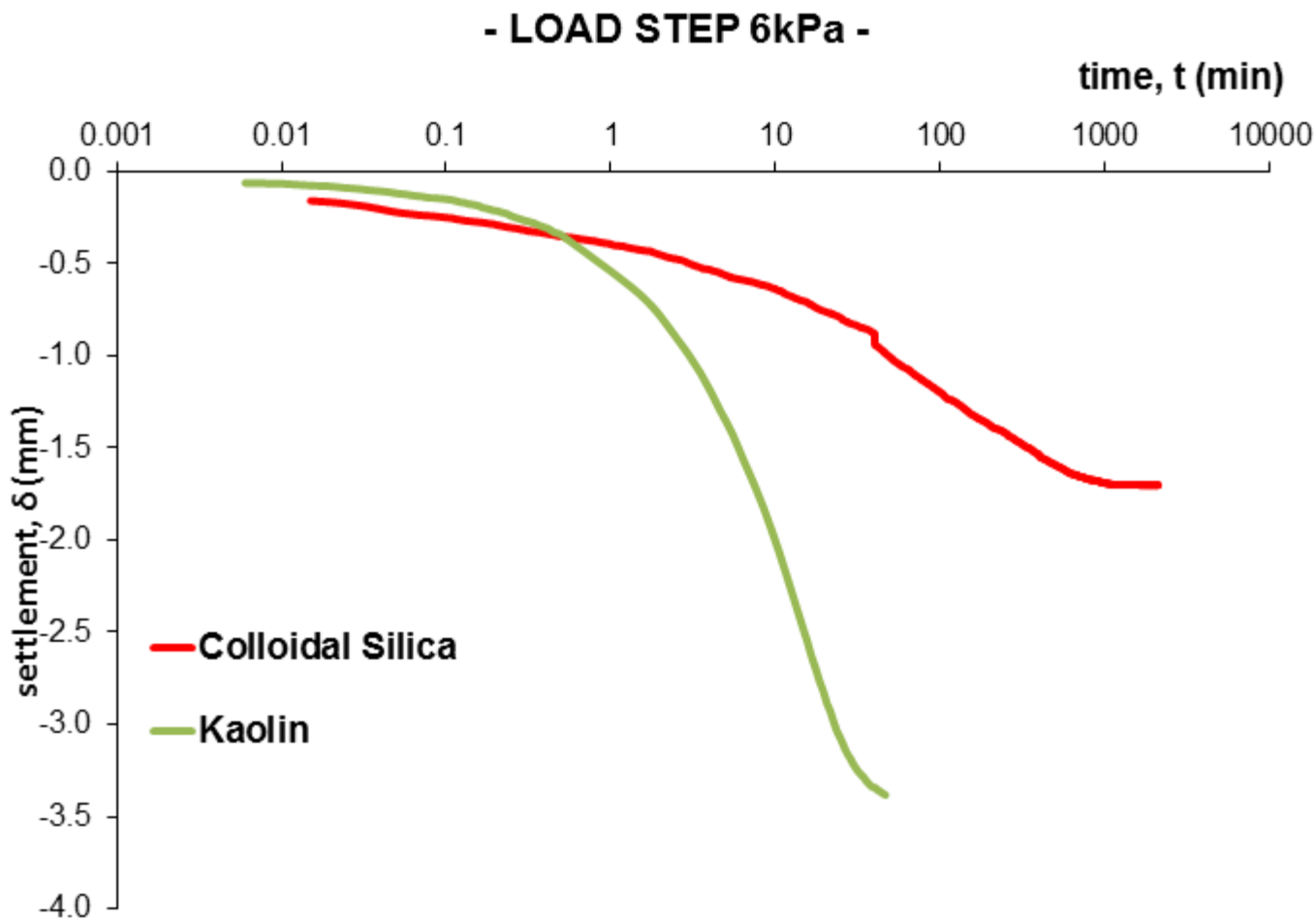
DISTINCTIVE

CONSOLIDATION BEHAVIOUR



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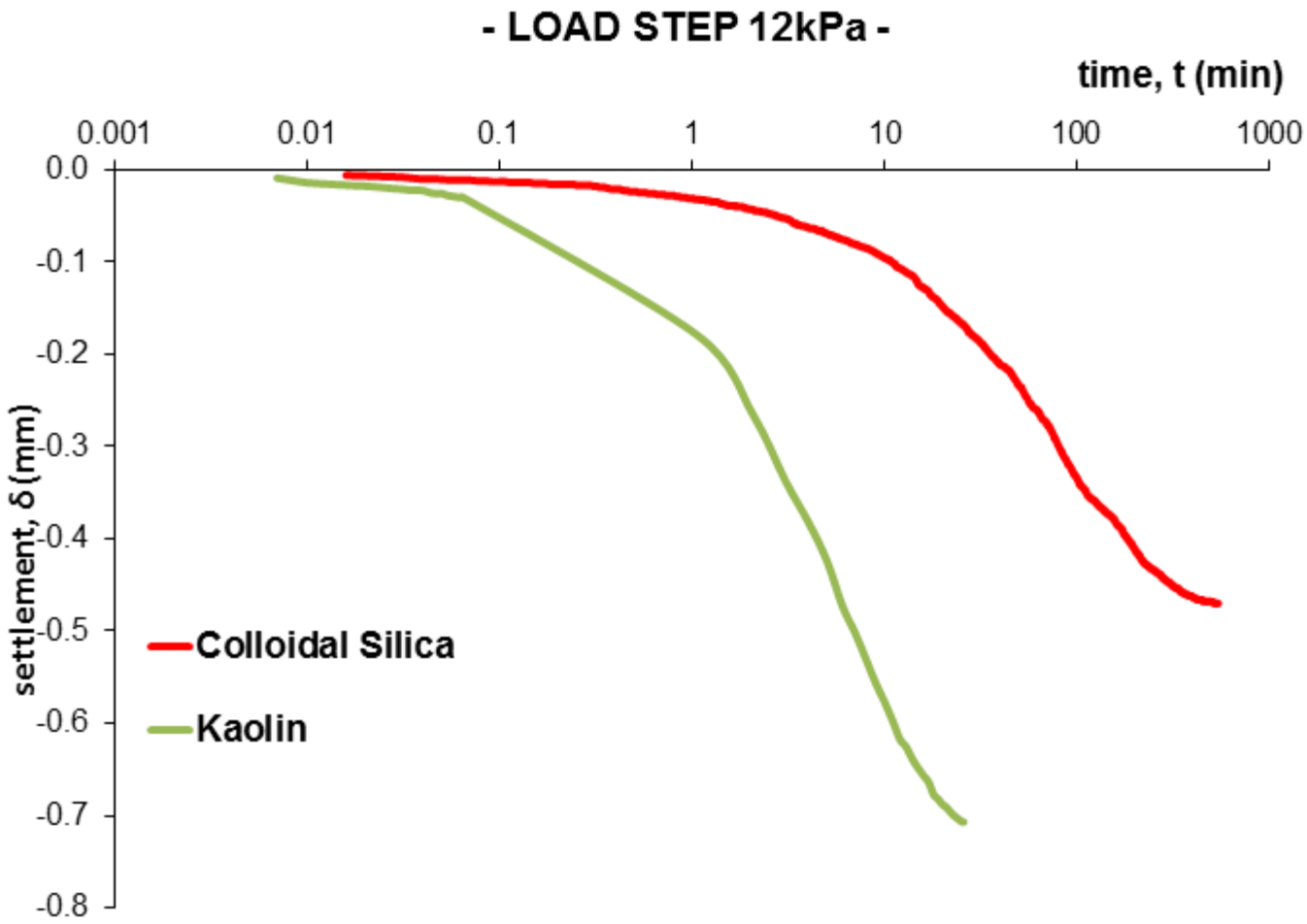

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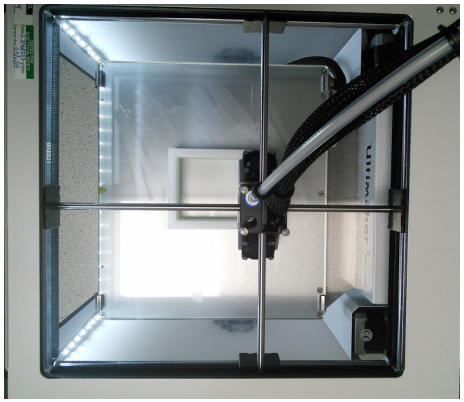
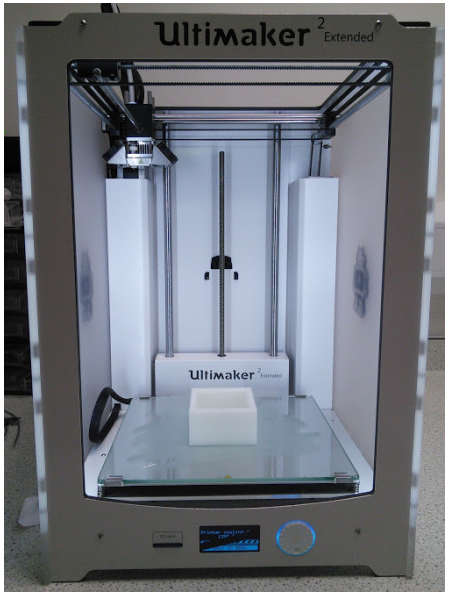
FUTURE WORK

- Shearbox testing
- Effect of curing time of colloidal silica grout
- Grout curing environment
- Testing in soil presences
- Hydraulic conductivity





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Thank you for your attention

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