Understanding the Rheological Behaviour of Tremie Concrete

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Introduction

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- Tremie placement is a commonly employed technique for deep foundation construction. The flow characteristics of concrete play a pivotal role in understanding both the ease of placement and the overall quality of the foundation.
- An excessively dense arrangement of piles in a group can lead to impairment in the curing process of fresh, young, and hardened properties of concrete. This can disturb the strength development of concrete, particularly as a result of dynamic installation of piles.
- Combining laboratory-scale experiments with field measurements can provide valuable insights.

Literature review

Sr No.	Purpose and year	Author(s)	Focus of paper	Key points
1	Guide to Tremie Concrete for Deep Foundations (2018)	By the joint EFFC/DFI Concrete Task Group	• Design considerations • Properties of concrete & mix design • Specifying and testing of concrete, quality control, execution, numerical modelling	• Behaviour of concrete as a Bingham fluid model. • Concrete mix design is a complex process. • Types of tremie flow is 'bulging' and 'plug'.
2	RILEM TC 266-MRP: round-robin rheological tests on high performance mortar and concrete with adapted rheology—rheometers, mixtures and procedures(2023)	Dimitri Feys, Mohammed Sonebi, Sofiane Amziane, Chafika Djelal, Khadija El-Cheikh, Shirin Fataei, Markus Greim, Irina Ivanova, Helena Keller, Kamal Khayat, Laurent Libessart ,Viktor Mechtcherine ,Ivan Navarrete ,Arnaud Perrot,Egor Secrieru ,Yannick Vanhove	• Describes mixture designs • Design and analysis of the experiments • Comparison of test results	• Developed flow curves, thixotropy interface, rheometry, friction stress and friction coefficient
3	Extension of the Reiner–Riwlin equation to determine modified Bingham parameters measured in coaxial cylinders rheometers (2012)	Dimitri Feys ,Jon E. Wallevik , Ammar Yahia , Kamal H. Khayat •,Olafur H. Wallevik	• The Reiner–Riwlin transformation equation is developed for the modified Bingham model	• Compatibility of Reiner–Riwlin equation • Numerical simulations applied on experimental data. • Modified Bingham model results in the most stable yield stress values
4	Report on Behaviour of Fresh Concrete During Vibration(2008)	Reported by ACI Committee	• Report covers rheological and mechanical processes • Principles of vibratory motion occurring during vibration, vibratory methods, and experimental results	• Knowledge of rheological properties is beneficial in selecting concrete mixtures • Further study required to provide the construction industry with test method for both laboratory and field. • Wave amplitudes and vibratory methods studied
5	Betonieren unter Verkehr Einfluss von Erschütterungen auf die Betonerhärtung (2021)	Sebastian Krohn, Michael Schrick, Reinhard Maurer	• Article refers hardening of concrete in the joint under vibrations caused by traffic flow. • concrete strength,cracking,bond of reinforcement were examined	• Traffic-induced vibrations and relative deformations • Edges of the joint have no negative influence on the strength development of concrete

Research significance

- Conditions of dynamic influence due to piling work have so far been neglected in the characterization of fresh, young, and hardened concrete properties.

- There is limited knowledge regarding:

1. Acceptable vibrations on fresh, young and hardened concrete and it effects on the concrete quality.

2. Parameters that determine degree of maturity of concrete i.e., shear rates, temperature, thixotropy, yield stress, plastic viscocity, fresh concrete properties

3. Characterisation of concrete damage at the microlevel.

Proposed experimental work

- Investigation of the influence of freshly concreted pile specimens under the energy input from ongoing vibration

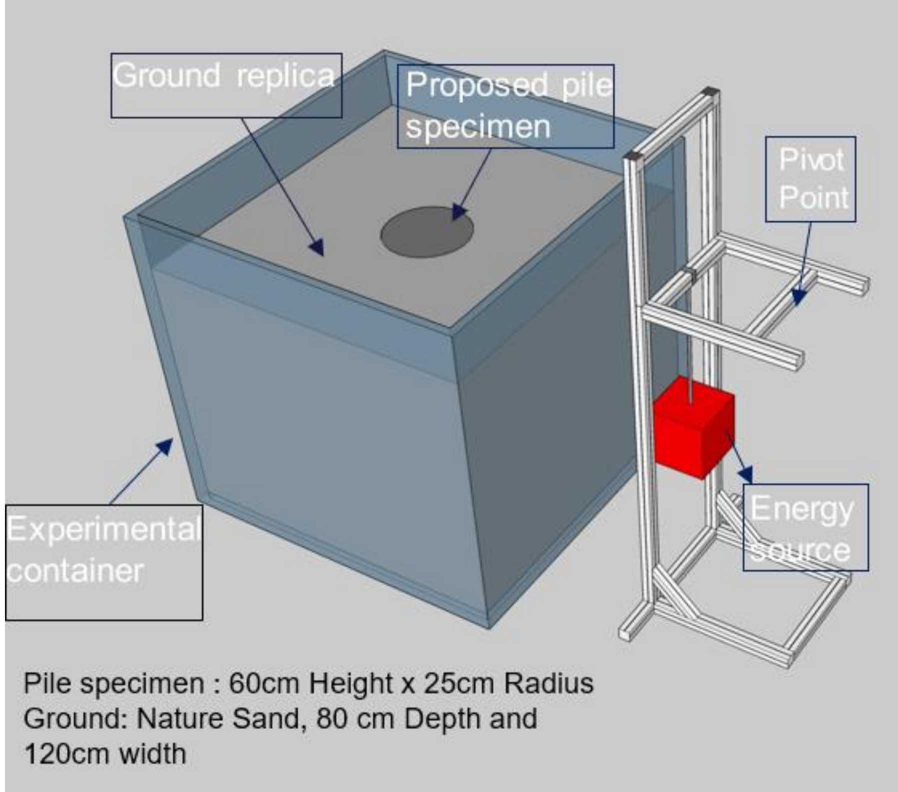
- Established tests for the characterisation of fresh, hardened concrete

- Investigation into the influence of vibrations on early-age concrete specimen

- Quantification of changes in fresh and hardened concrete characteristics

Proposed laboratory test method

- To reproduce the original on-site ramming effect, hammer pendulum is constructed.
- Horizontal vibrations are considered during the process.
- Dimensioning of the hammer weight for this pendulum is carried out by considering mass, force and drop height obtained from field piling work.
- A pivot is placed for controlling the swinging motion.



Advantages

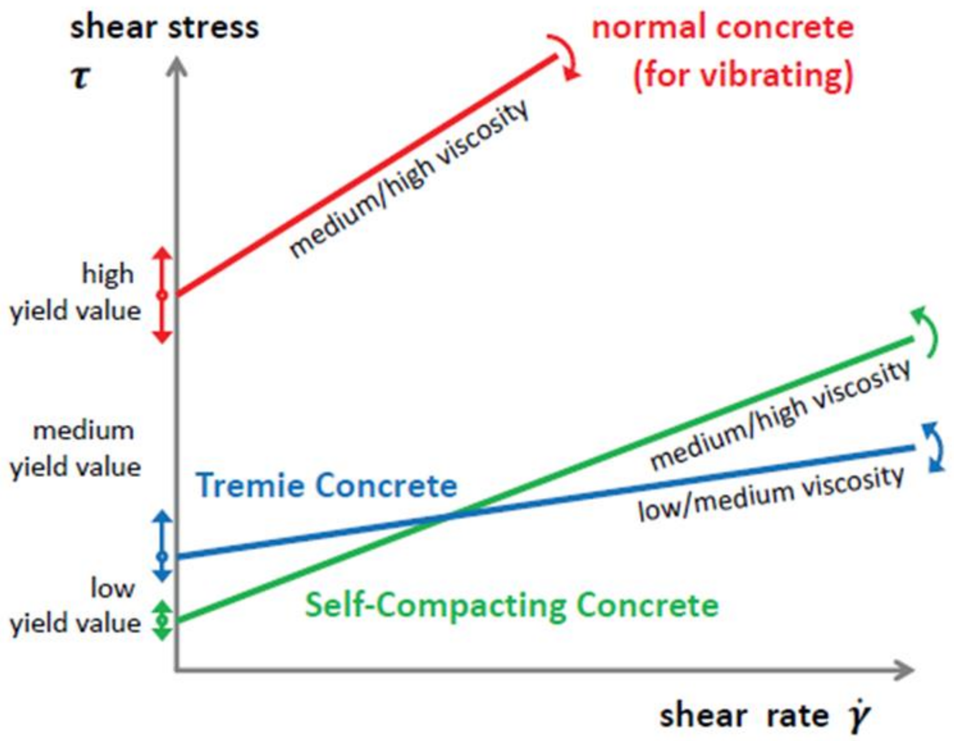
- Dynamic behaviour analysis
- Concrete characterization analysis
- Simulate real situation
- Cost effective testing

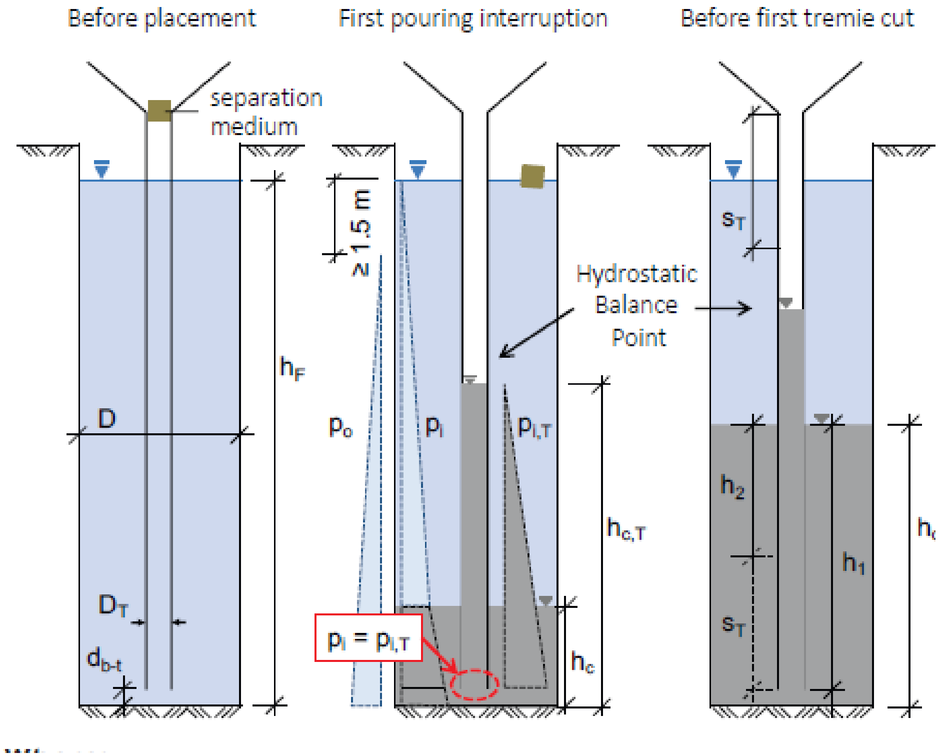
Tremie placed concrete

- Tremie pipe is a segmental pipe with waterproof joints used to pour concrete
- Tremie placement enables a controlled & continous pouring
- Ideal situation is the ability to flow around obstacles
- Specific guidelines for enabling onsite testing includes selection, design of pipe, concrete mix design, consistency etc.

Source : www.theconstructionindex.co

Rheology measurements for a deep foundation





Source: Guide to Tremie Concrete for Deep Foundations By the joint EFFC/DFI Concrete Task Group

Conducted testing

- Yield stress, plastic viscosity measurements
- Testing methods in laboratory and field
- Difference in the speed profiles of rheometer
- Characterisation of concrete responses

Conducted test significance

- To comprehend how concrete responds to different shear rates and improve concrete pumping efficiency.

- To maintain controlled flow within the tremie pipe during concrete placement.

- To measure the yield stress and viscosity of the concrete used in deep foundation construction.

- To ensure workability of fresh concrete, ease of placement, and quality control.

Testing methods

- eBT-V Schleibinger mobile Rheometer for fresh concrete
- Test conducted on concrete delivered in the construction site
- Test conducted in controlled laboratory environment
- Measured plastic viscosity and yield stress
- Rheological parameters obtained using Bingham equation T = g + h·N

  where, g-relative yield stress; h-relative viscosity
- Rheological parameters yield stress and plastic viscosity obtained using

Reiner-Riwlian equation $G_x = \dfrac{4\pi h_x \text{In}\left(\frac{R_{o,x}}{R_{i,x}}\right)}{\left(\frac{1}{R^2{}_{i,x}} - \frac{1}{R^2{}_{o,x}}\right)} \tau_0$

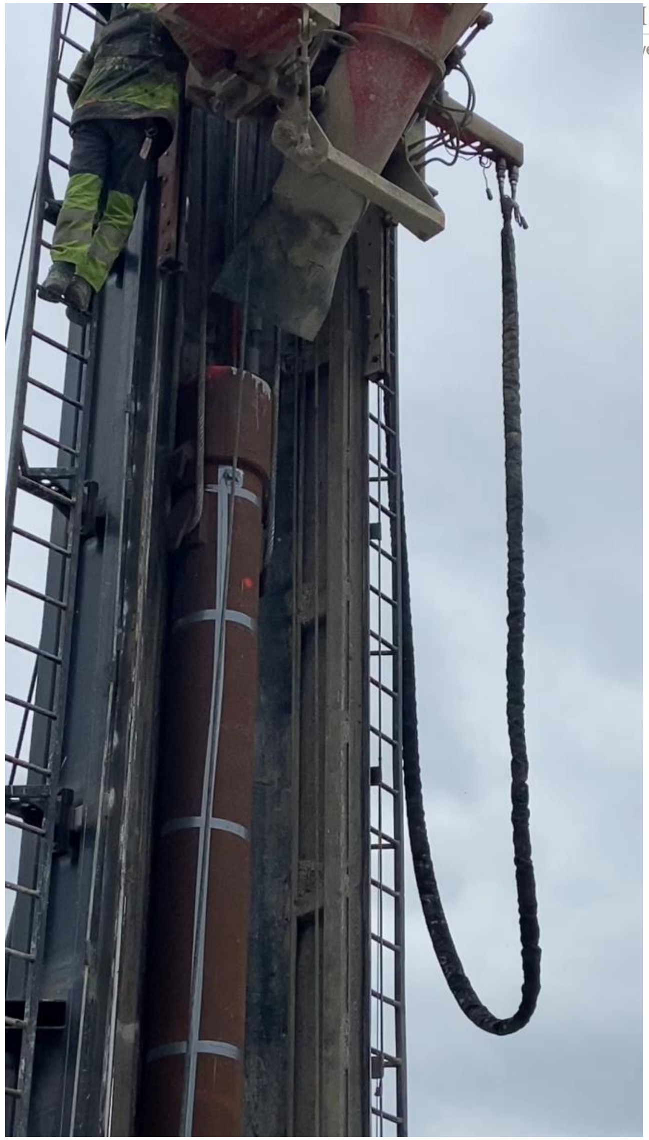
$$H_x = \frac{8\pi^2\ h_x}{\left(\frac{1}{R^2{}_{i,x}} - \frac{1}{R^2{}_{o,x}}\right)} \mu_p$$

Test program

Test program conducted on laboratory with
eBT-V rheometer using ramp up down shear profile

Test program conducted on a construction site in Hamburg, focusing on deep foundation testing, utilized the eBT-V rheometer and employed a step-down shear profile.

Test program



Concrete details

Concrete produced in lab

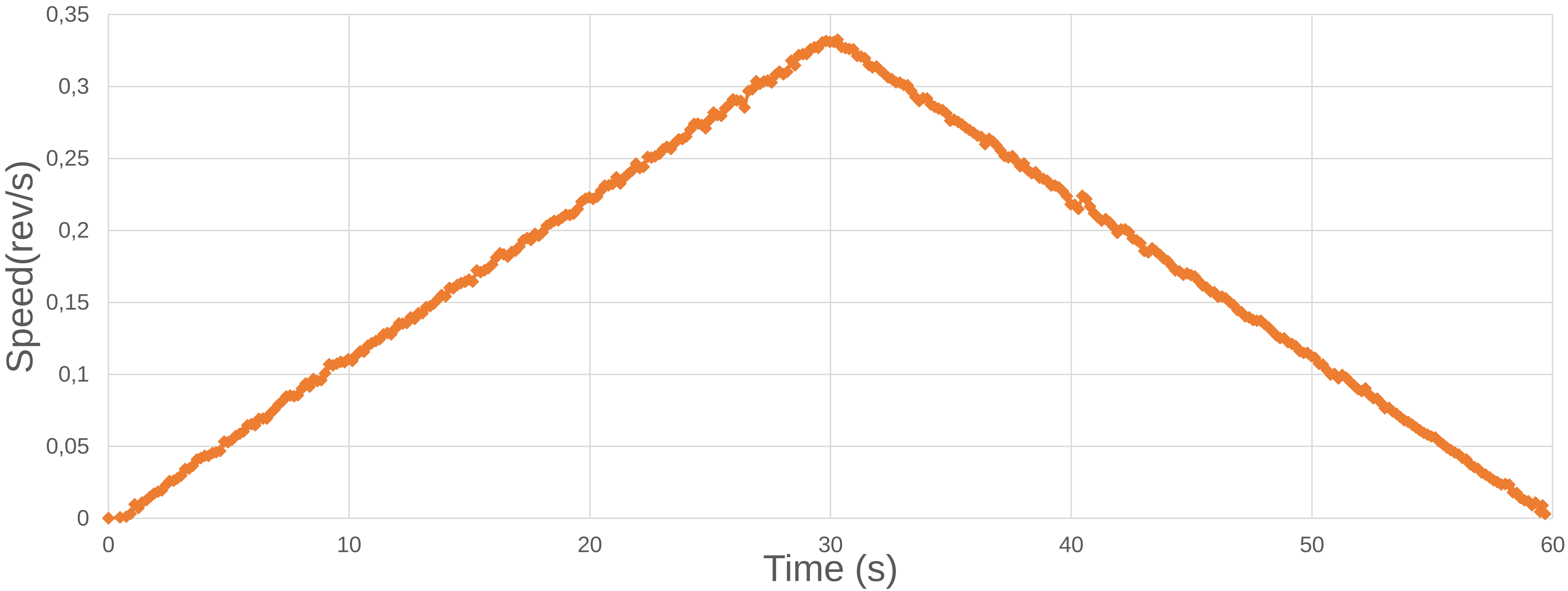
Component	Content
Cement CEM III/B 42,5 L-LH/SR (NA) [kg/m³]	340
water[kg/m³]	160
w/c ratio	0.47
Sand 0/2 [kg/m³]	657
Gravel 2/8 [kg/m³]	745
Gravel 8/16 [kg/m³]	414
Superplasticizer [Kg/m³]	2.89
Slump flow[mm]	598
Consistency	F5

Details provided by the contractor on the construction site

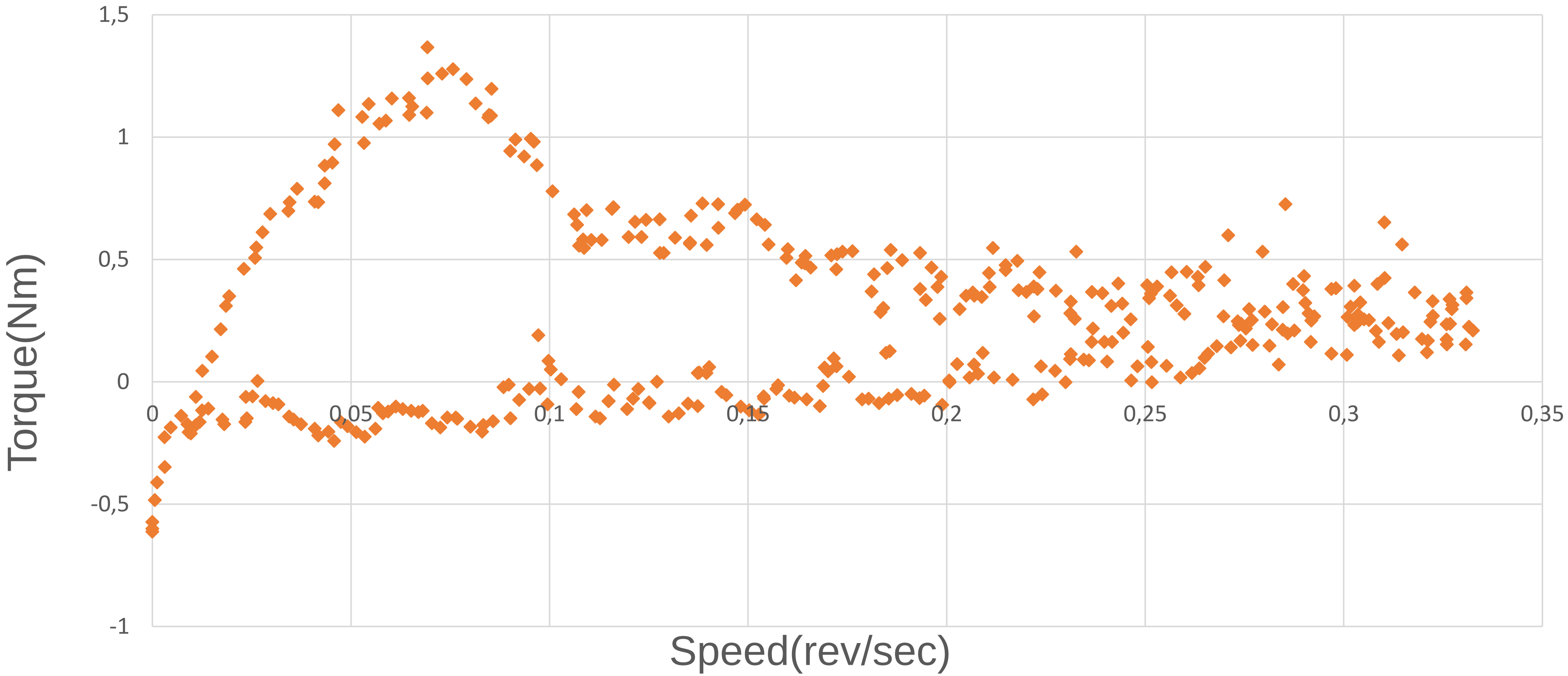
Component	Content
Cement CEM I 42,5R(NA) [kg/m³]	389.6
Fly ash[kg/m³]	50
w/c ratio	0.42
water[kg/m³]	167.2
Sand 0/2 [kg/m³]	708
Gravel 2/8 [kg/m³]	354
Gravel 8/16 [kg/m³]	708
Superplasticizer [Kg/m³]	3.72
Retardant [kg/m³]	1.17
Slump flow[mm]	594
Consistency	F5

Test results: Rheometer ramp up down speed profile

- Rotational speed increased from 0 rev/s to 0.3 rev/s and decreased from 0.3 rev/sec to 0 rev/s in 60 s



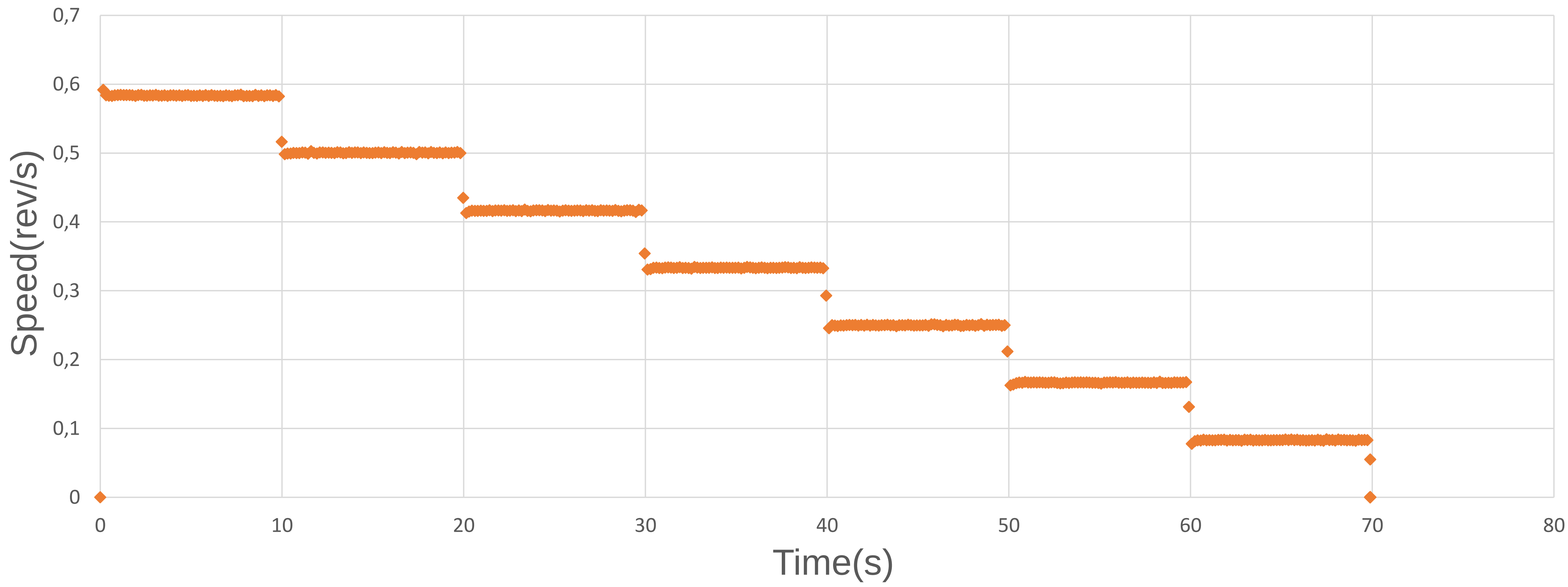
Test results: Flow curve



Bingham by Reiner – Riwlin
Yield stress = -128.27Pa
Plastic viscosity = 141.78 Pa·s

Test results: Step down speed profile

- Rotational speed increased from 0 rev/s to 0.6 rev/s
- Rotational speed decreased stepwise, each step lasting for 10 s



Test results: Flow curve

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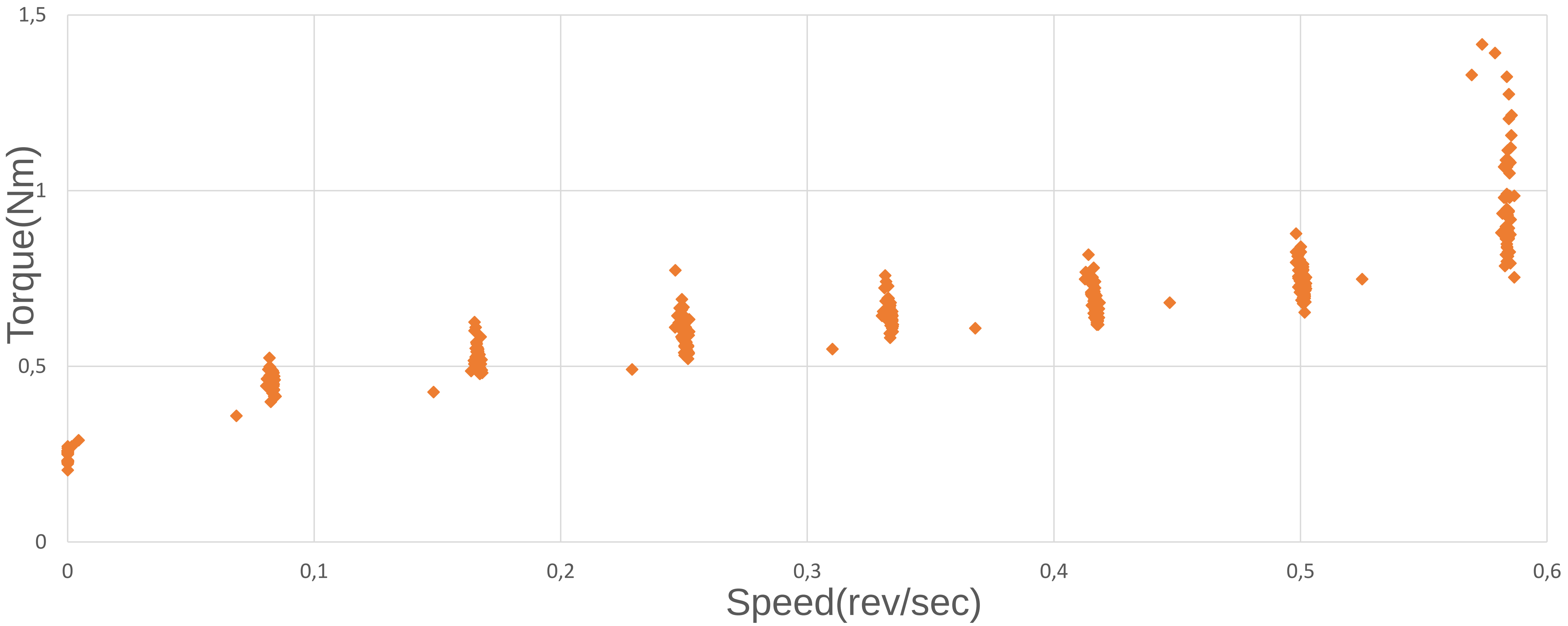


Bingham by Reiner – Riwlin
Yield stress = 107,03 Pa
Plastic viscosity = 28,89 Pa·s

Conclusion

- With ramp up down profile

  Yield stress = -128.27 Pa

  Plastic viscosity = 141.78 Pa·s

- Step down profile gives more realistic understanding about Tremie placed concrete

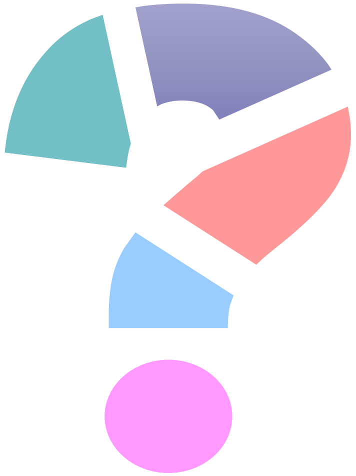
  Yield stress = 107.03 Pa

  Plastic viscosity = 28.89 Pa·s

- Range of yield stress and plastic viscosity with step down profile

  Yield stress = 84.17 Pa – 107.03 Pa

  Plastic viscosity = 24.91 Pa·s – 29.14 Pa·s



Does the yield stress and plastic viscosity range meet the requirements for tremie-placed concrete?

Does the calibration of the rheometer affect the results, and what is the procedure for carrying it out?

Should the measurement time and speed be kept short or long to minimize any negative effects?

Outlook

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- Implementing field insights into laboratory investigations.
- Validating and refining observations through comparisons between field and laboratory investigations.
- Investigating the impact of ramming energy on various aspects of fresh, young, and hardened concrete in extensive laboratory studies.

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Thank you for the attention

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