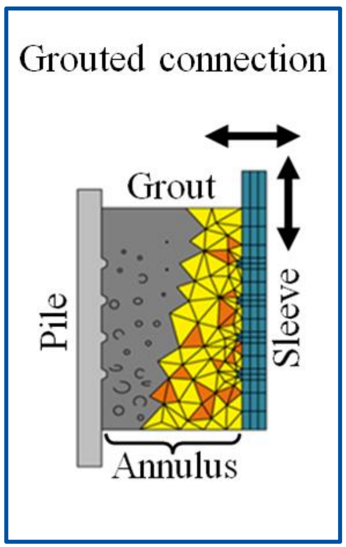
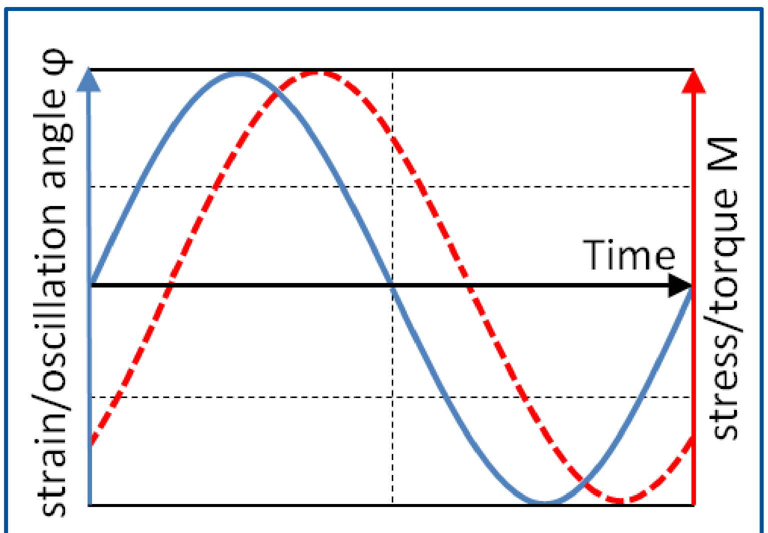
28th Conference: "Rheologische Messungen an Baustoffen 2019"

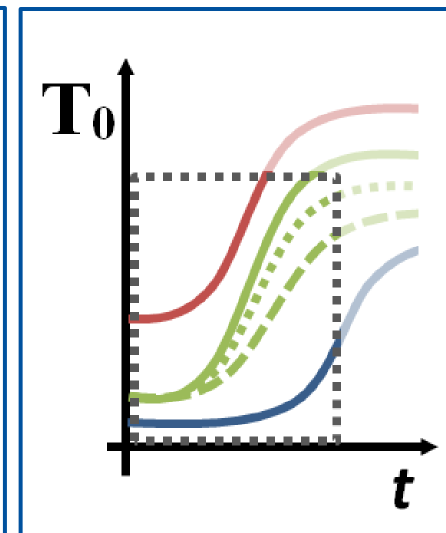
Rotatorische und oszillatorische Scherversuche zur Ermittlung steifigkeitsrelevanter Kenngrößen von Offshore-Vergussmörteln unter dem Einfluss des Early-age Movement

Rotational and Oscillatory Shear Tests for Determining Time-dependent Properties of Offshore Grouts under the Influence of Early-age Movement

Cotardo, D., Begemann, C., Haist, M., Lohaus, L.







Leibniz Universität Hannover

March 13th, 2019 – OTH-Regensburg

GREAM

IfB Institut für Baustoffe

INTRODUCTION

Wave-induced loadings

↓

Relative movements between pile and sleeve during the initial setting of grout

↓

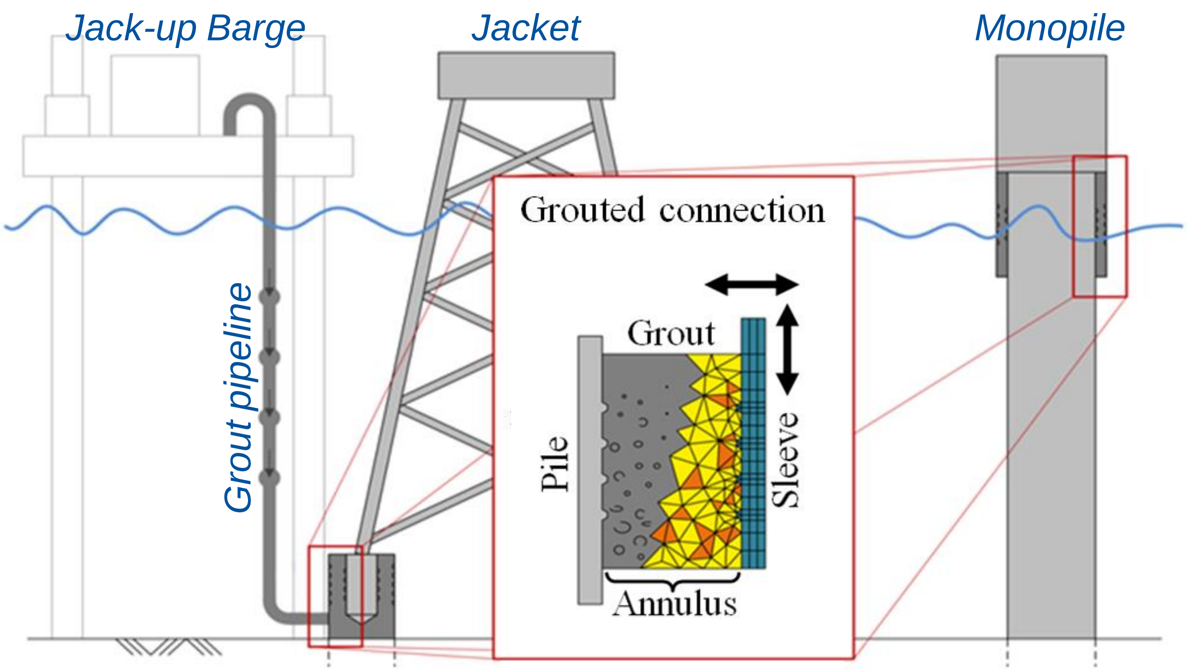
Early-age Movement (EAM)

↓

Effect of EAM on the mechanical properties of grout is unknown

↔

DNVGL-ST-0126, 2018:
Relative movements shall be limited to a maximum of 1 mm, whereby ungrouted connections shall be considered



MOTIVATION

DNVGL requirement (1 mm) leads to severe restrictions and additional costs

↓

Implications for the installation and design process		
Greater displacements already occur at relatively calm sea	Necessity for additional measures in order to secure grouted connections	Uncertainties in the design process
↓	↓	↓
Expansion of the installation time slot could lead to economic advantages	Sacrifice of cost-intensive measures (e.g. pile gripper)	More economical design of offshore support structures and knowledge of lifespan

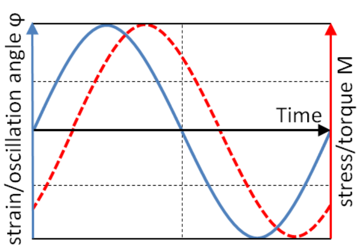
Benefits for the installation and design process by knowledge of the effects of EAM

GOAL

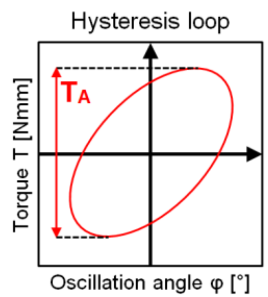
The goal was to provide a method for determining time-dependent properties of grout under the influence of Early-age Movement

Oscillatory rheology in order to

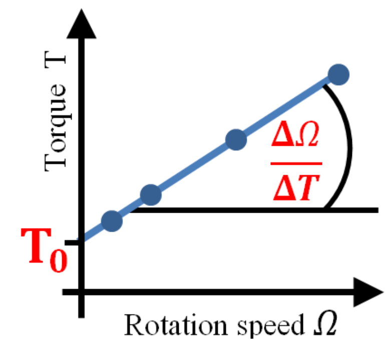
simulate wave-induced relative movements



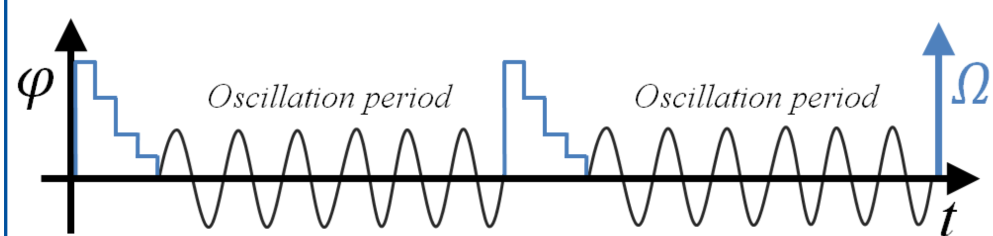
determine the development of grout properties



Rotational rheology for determining material characteristics



Combination of both methods



EXPERIMENTAL PROGRAMME

SAMPLES

Flowability as a function of w/s ratio

A	B	C
$Ø_A = 150$ mm	$Ø_B = 300$ mm	$Ø_C = 450$ mm

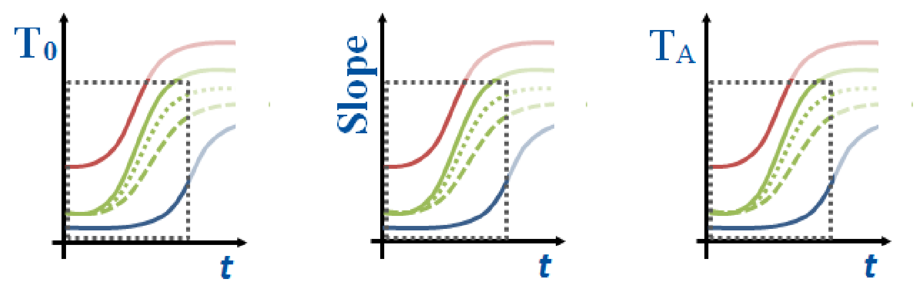
↔ Influence of the material properties

ROTATIONAL AND OSCILLATORY RHEOLOGY

A	B	C
$\varphi = 10°$	$\varphi = 0°$ $\varphi = 1.5°$ $\varphi = 10°$	$\varphi = 10°$

↔ Influence of the oscillation angle φ

Representation of the development of grout-stiffness



↔ Influence of the EAM on the development of grout properties

DETERMINATION OF THE COMPRESSIVE STRENGTH

Undisturbed and disturbed

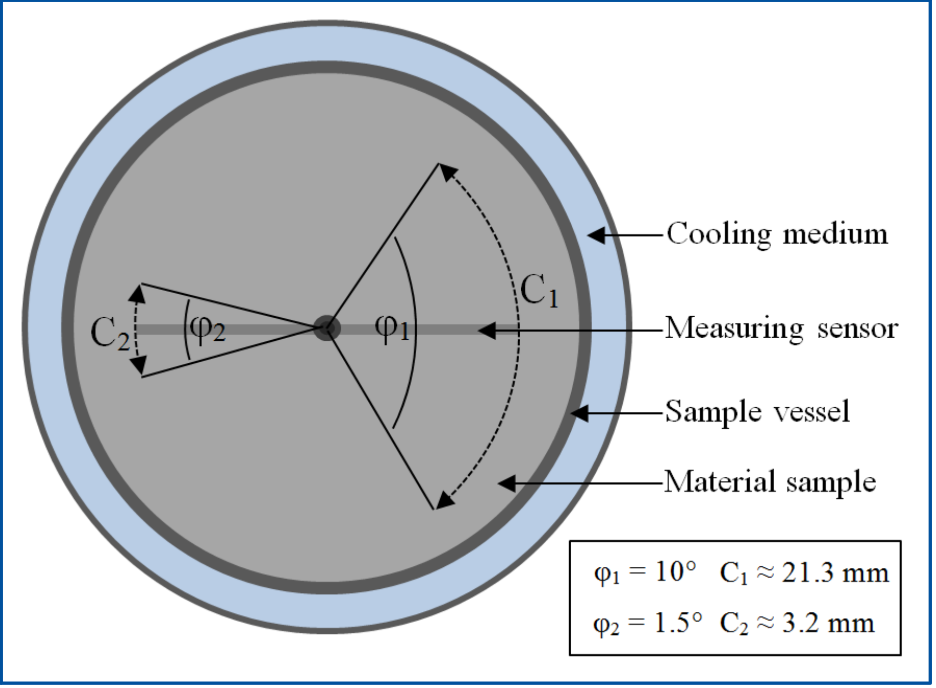
↔ Influence on the strength

METHODS

Implementation of the investigations

Viskomat XL

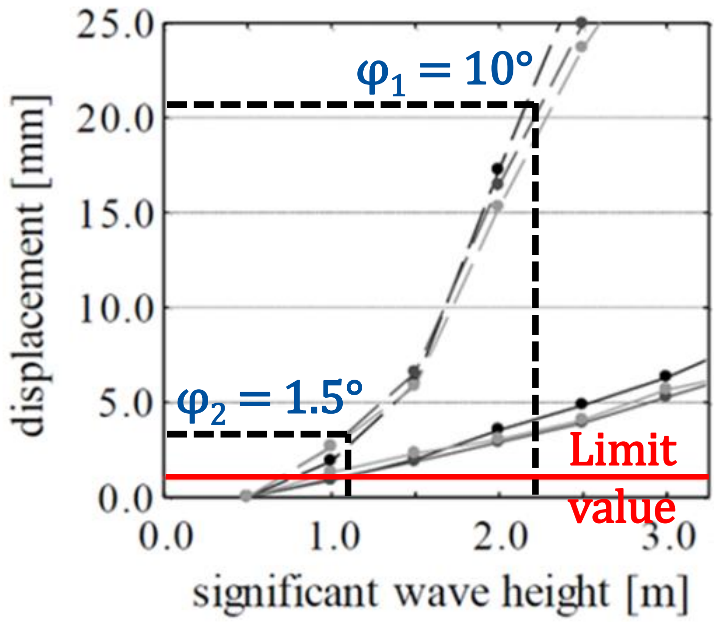
Concrete paddle

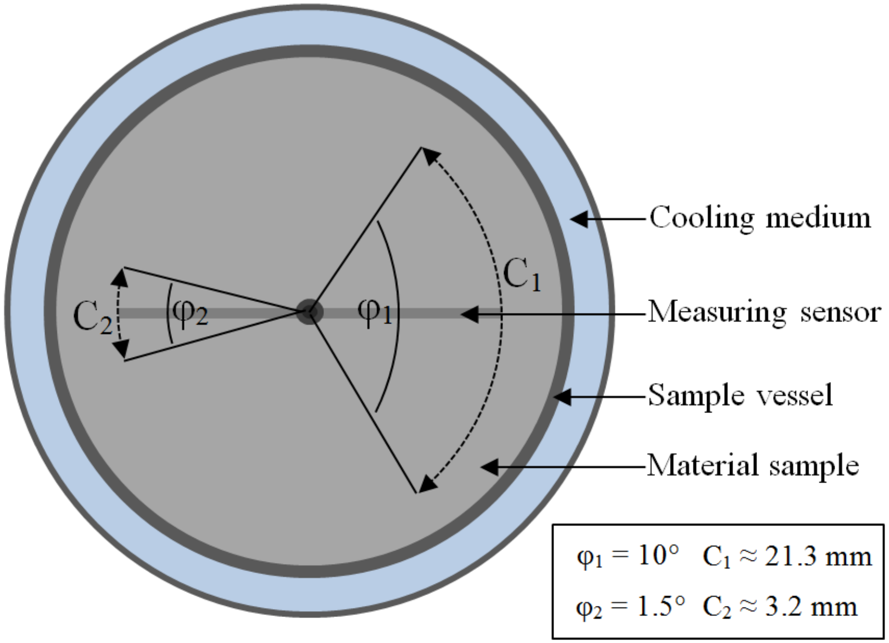


Resulting relative displacement depending on the rotation angle φ and the geometry of the measuring sensor

METHODS

Implementation of the investigations

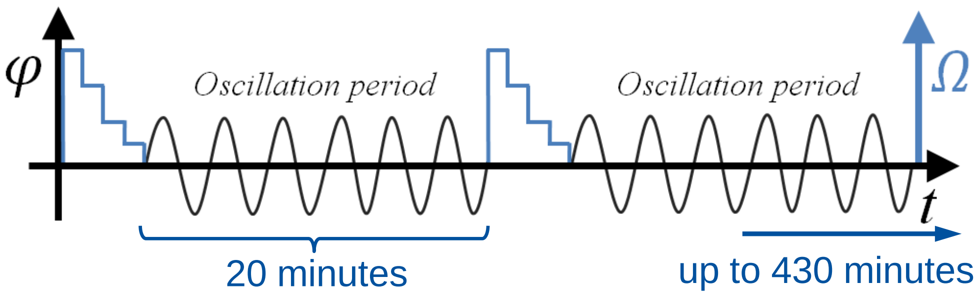




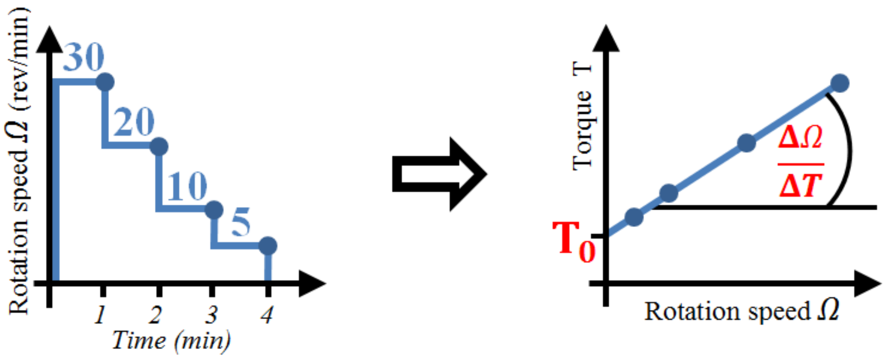
Numerical investigations: Relative displacement of a monopile substructure depending on the significant wave height

Resulting relative displacement depending on the rotation angle φ and the geometry of the measuring sensor

METHODS



Sequence of the measurement profile



Flow curves generated from a downward step profile

Rheological form

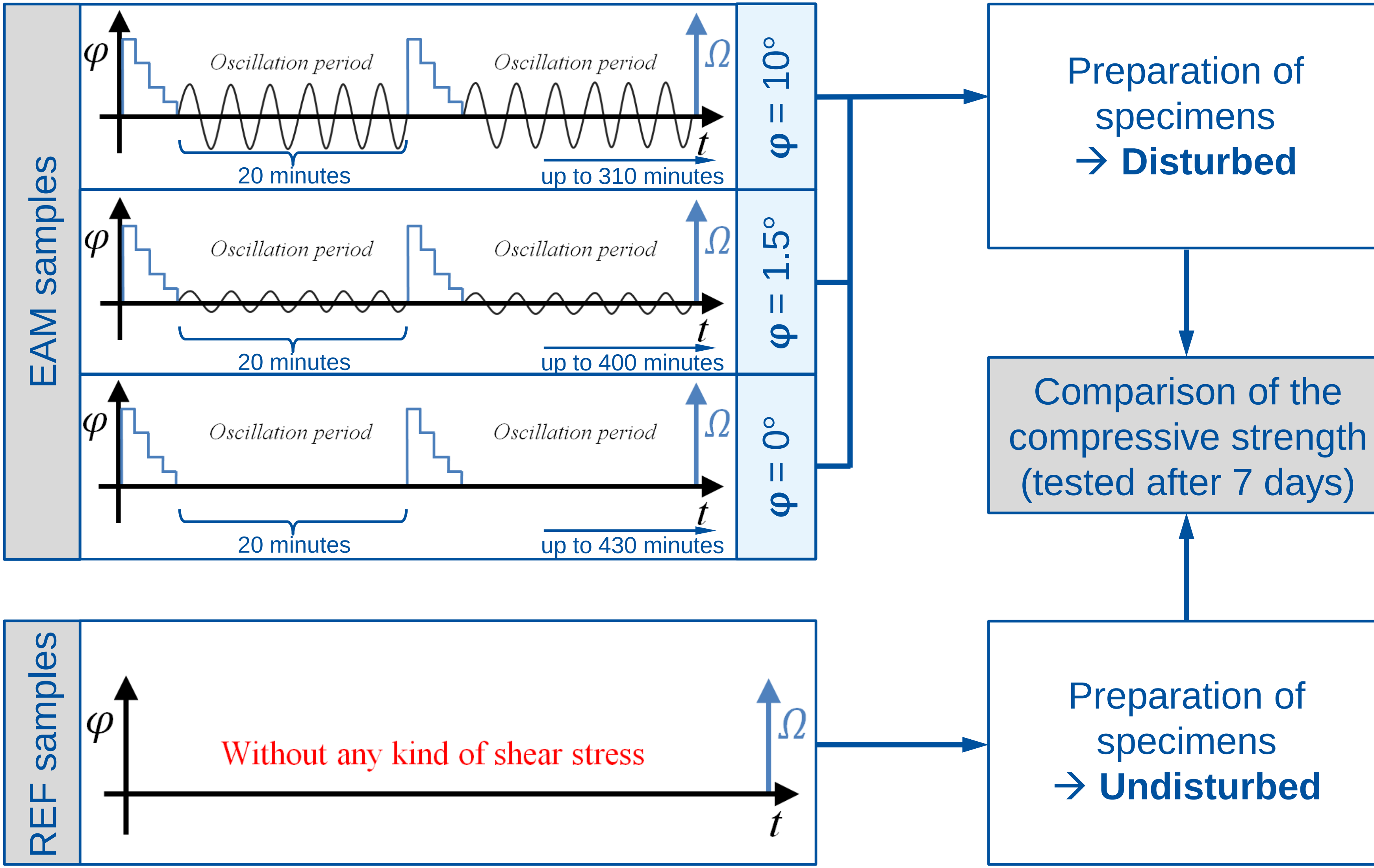
$$\tau(\dot{\gamma}, t) = \tau_0(t) + \mu(t) \cdot \dot{\gamma}$$

'BINGHAM model'

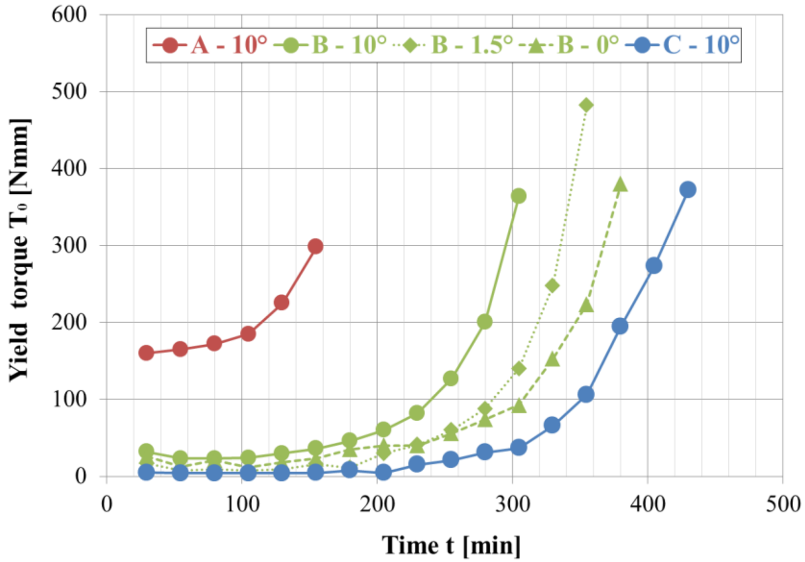
Rheometric form

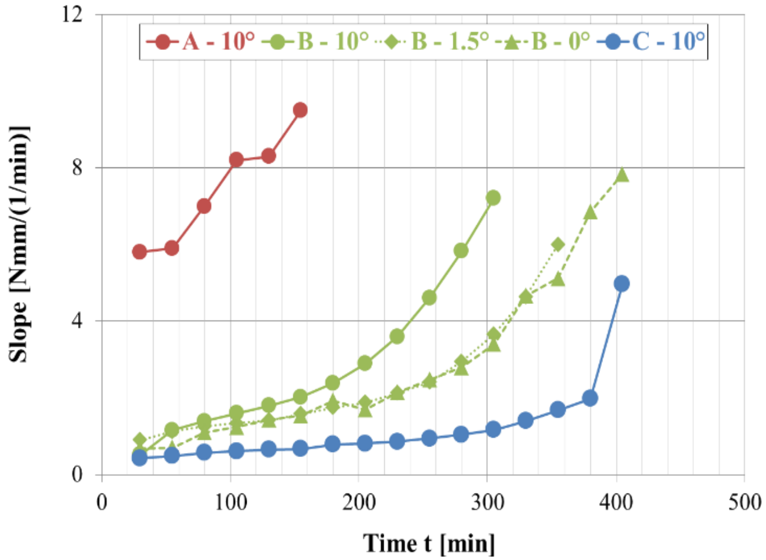
$$\mathrm{T}(\Omega, t) = \mathrm{T}_0(t) + \frac{\Delta\Omega}{\Delta T}(t) \cdot \Omega$$

METHODS


EAM samples
φ
Oscillation period
Oscillation period
Ω
t
20 minutes
up to 310 minutes
φ = 10°
φ
Oscillation period
Oscillation period
Ω
t
20 minutes
up to 400 minutes
φ = 1.5°
φ
Oscillation period
Oscillation period
Ω
t
20 minutes
up to 430 minutes
φ = 0°
REF samples
φ
Without any kind of shear stress
Ω
t
Preparation of specimens → Disturbed
Comparison of the compressive strength (tested after 7 days)
Preparation of specimens → Undisturbed

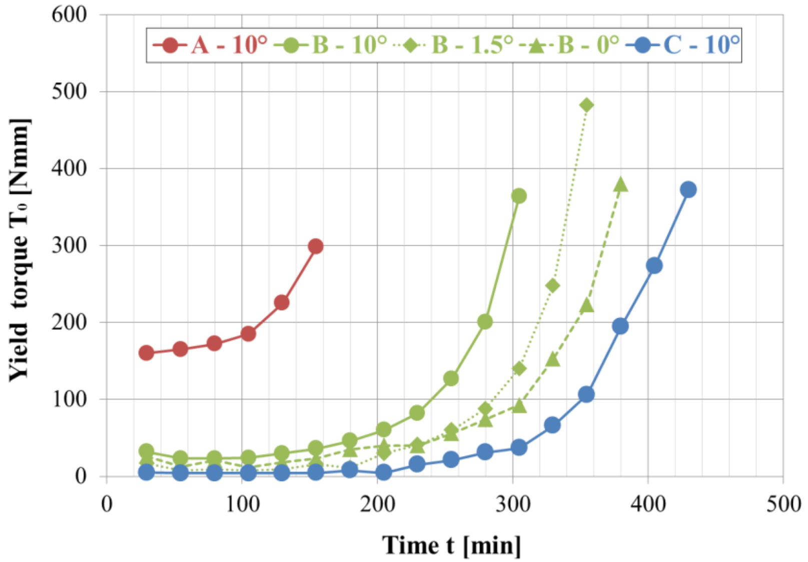
RESULTS AND DISCUSSION

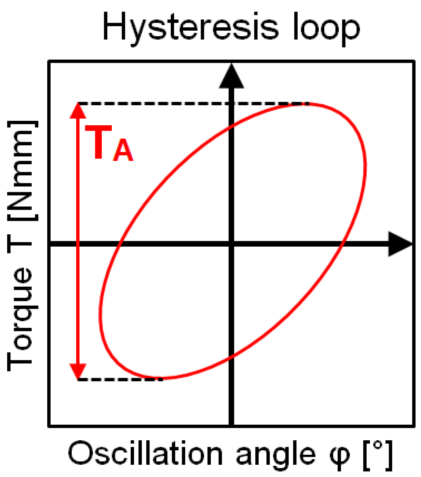


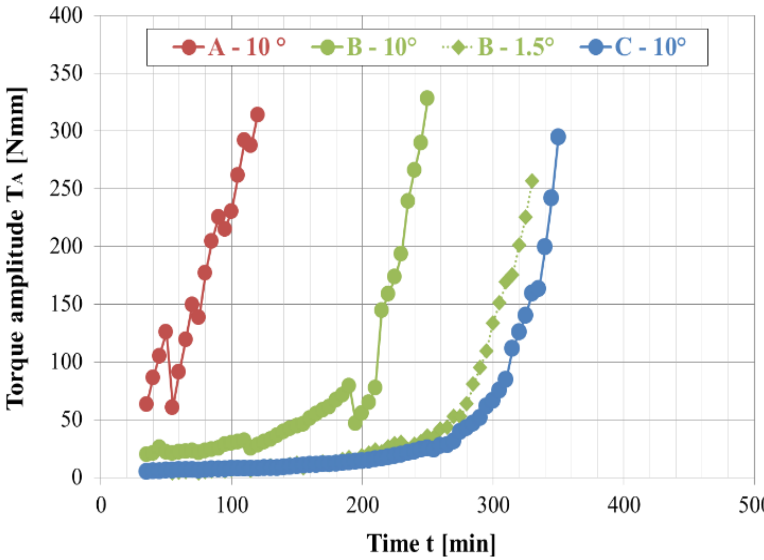


Results	Discussion
→ The lower the w/s ratio, the more accelerated an increase in grout properties → A greater oscillation angle φ causes an accelerated increase in grout properties	→ Pore spaces can be bridged faster by the growth of early hydration products → Primary structures are formed by the externally applied shear stress → Permanent cyclical movements lead to a process of deaeration → Due to abrasion of hydration products, the time span of the dormant period is reduced

RESULTS AND DISCUSSION

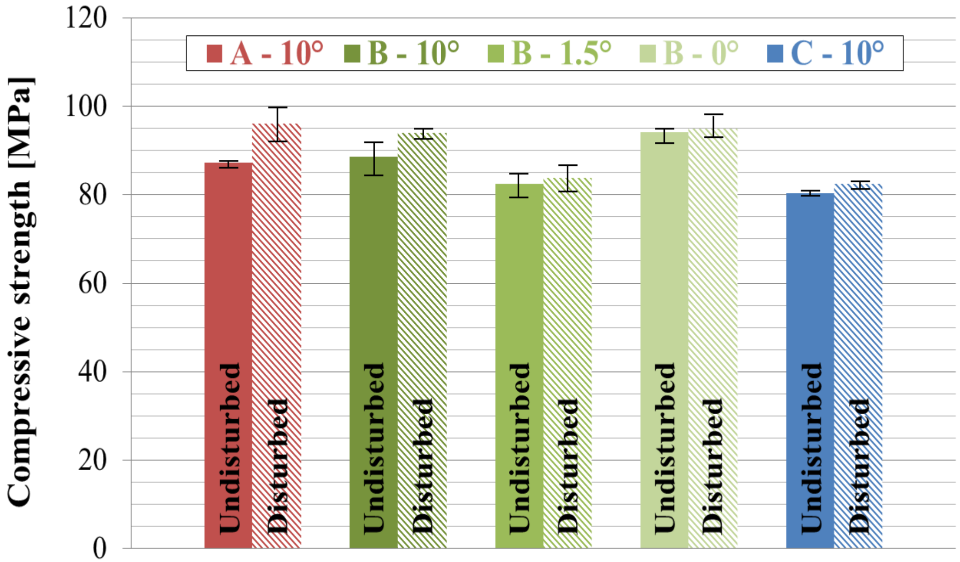






The torque amplitude T_A of the oscillation tests themselves also reflect the described relationships

RESULTS AND DISCUSSION



Results	Discussion
→ Permanent cyclical movements lead to greater compressive strength (disturbed samples) → The higher the initial flowability of the material, the lower the influence of cyclic movements on the compressive strength	→ Permanent cyclical movements lead to a process of deaeration, which increases the compressive strength Shear stress could lead to abrasion of hydration products, which acts as precipitation nuclei during the hydration period of hardening

SUMMARY

Effect of w/s ratio on the time-dependent grout properties	Effect of oscillation angle φ on the time-dependent grout properties
The lower the w/s ratio the more accelerated the increase in grout properties → Pore spaces can be bridged faster	Greater oscillation angle φ causes an accelerated increase in grout properties → Process of deaeration occurs → Extrinsic agglomeration occurs → Acceleration period commences earlier

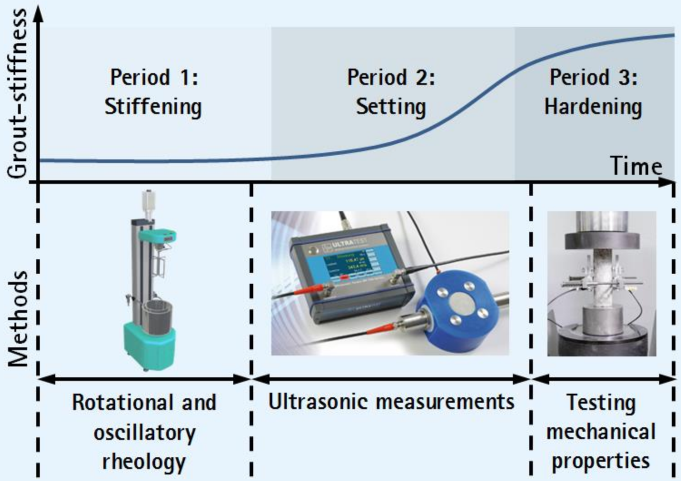
Effect of EAM on the compressive strength
Permanent cyclical movements lead to greater compressive strength → Process of deaeration occurs → Colloidal hydration products act as precipitation nuclei during the hydration period of hardening, if the shear rate is high enough → **No impairment due to EAM on strength was observed**

CONCLUSIONS

Rheological method	Recommendation for the practice
The method for simulating the EAM via oscillation is very promising → This type of cyclic movements closely resembles wave-induced loads → Varying deflections and frequencies can be simulated	The lower the w/s ratio… → the lower are segregation phenomena, → the more accelerated the development of grout properties, → the greater the strength of the hardened grout.
The combination of rotation and oscillation allows a deep understanding of the rheological behavior	The flowability must be high enough for the material to be pumped!!

OUTLOOK

Further methods		Goals
Determination of the air void content of the hardened grout	→	Verification of the process of deaeration due to cyclical movements
Conductivity measurements	→	Verification of abrasion processes due to shear stress
Particle size analysis	→	Verification of the effect of extrinsic agglomeration
Determination of the material behavior over a period of 24 hours	→	Representation of a comprehensive property profile of the grout from the liquid to the hardened state



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GREAM

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Thank you for your attention!

Dipl.-Ing. Dario Cotardo
Research Staff

Institute of Building Materials Science
Appelstraße 9A
30167 Hannover

d.cotardo@baustoff.uni-hannover.de

www.baustoff.uni-hannover.de

Leibniz Universität Hannover