

# Rheology of Building Materials

## 21<sup>st</sup> Conference

# Measuring and adjusting rheological parameters during the mixing process

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# Introduction

SCC is sensitive to:

- small variations in the properties of the constituent materials
- batching accuracy
- variation in the mixing process.

At the mixing plants, current manufacturing technology is not always capable of producing SCC with specified rheological properties at an acceptably low batch to batch variation.

The Visco Probe system is one of the first systems to provide a measure of the rheological behaviour directly in the mixer. Including a decision-making system it may be one step forward towards more consistent SCC production.

# Introduction

Important to note that bringing the concept of rheology into practice is not an easy matter.

A lot of people involved in every day SCC production do not know the term rheology and the associated terms Bingham, shear stress, shear rate, yield stress and plastic viscosity.

Very often SCC is characterised qualitatively using words like wet, dry, sticky and stiff.

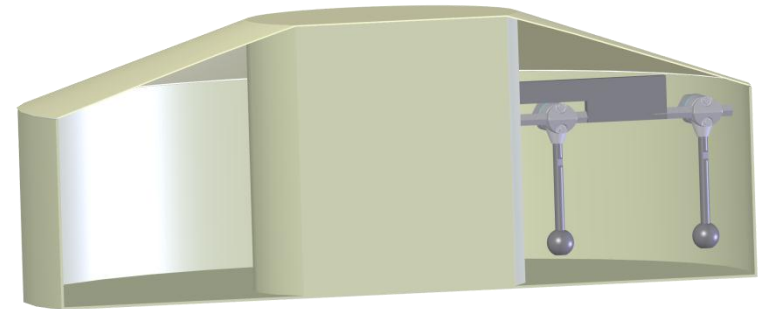
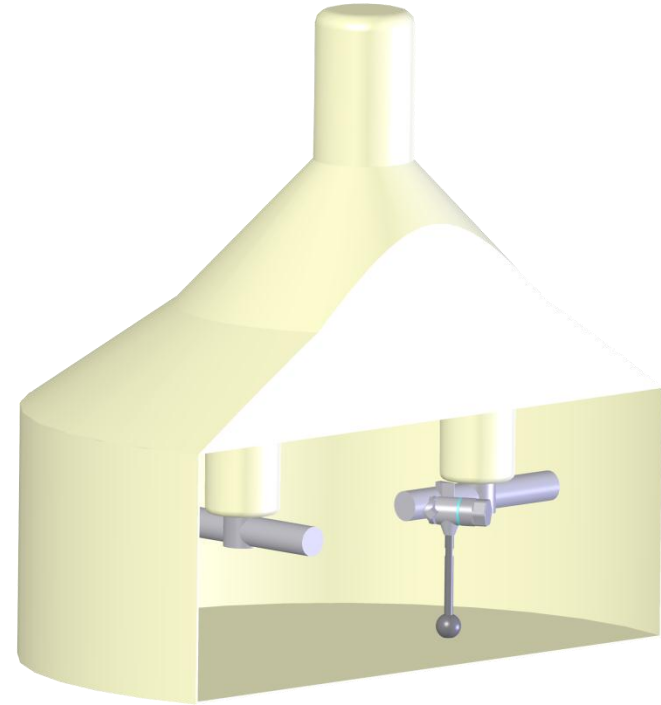
Often, the slump flow is the only quantitative measure used in production control (only limited number of batches).

# Aim of study

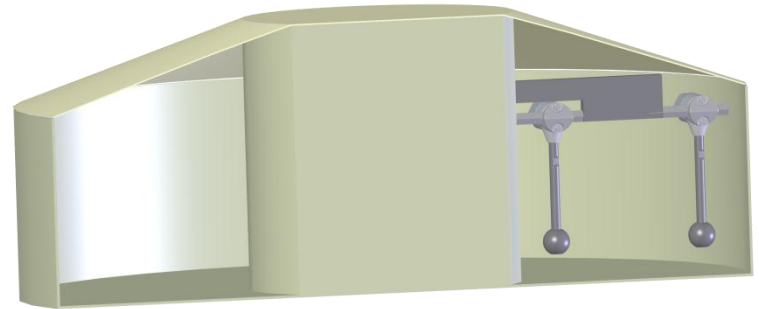
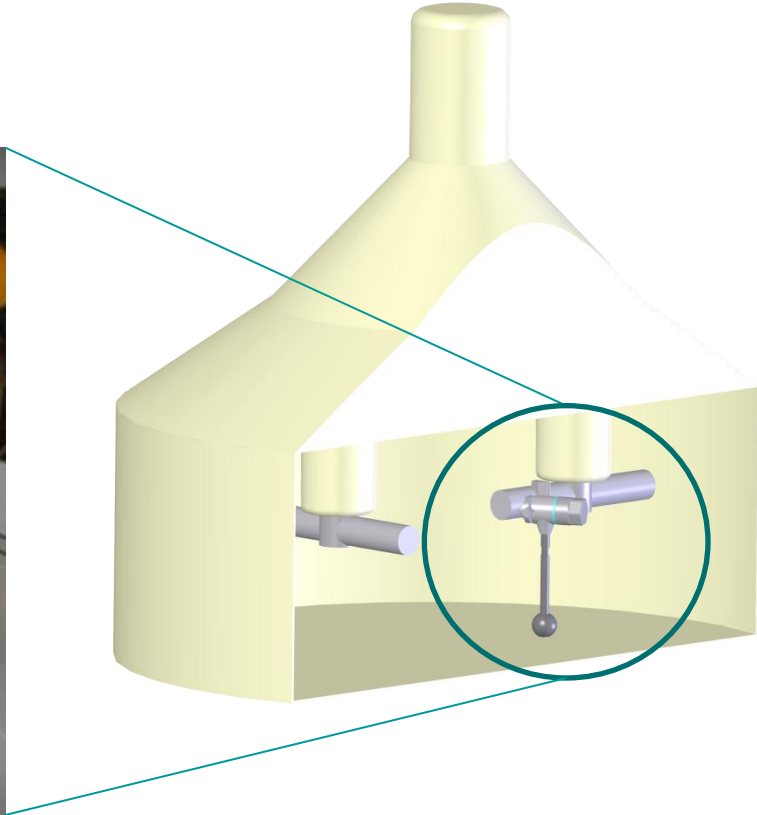
To compare the Visco Probe response in full scale production with fundamental values of yield stress and plastic viscosity measured by the 4C-Rheometer.

Based on the above, to establish mathematical procedures to translate “arbitrary” rheological parameters measured by the Visco Probe into physical values.

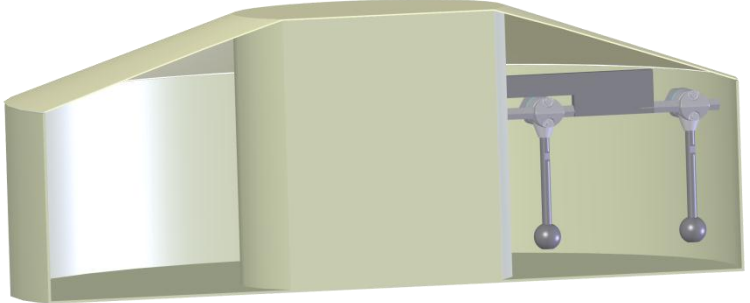
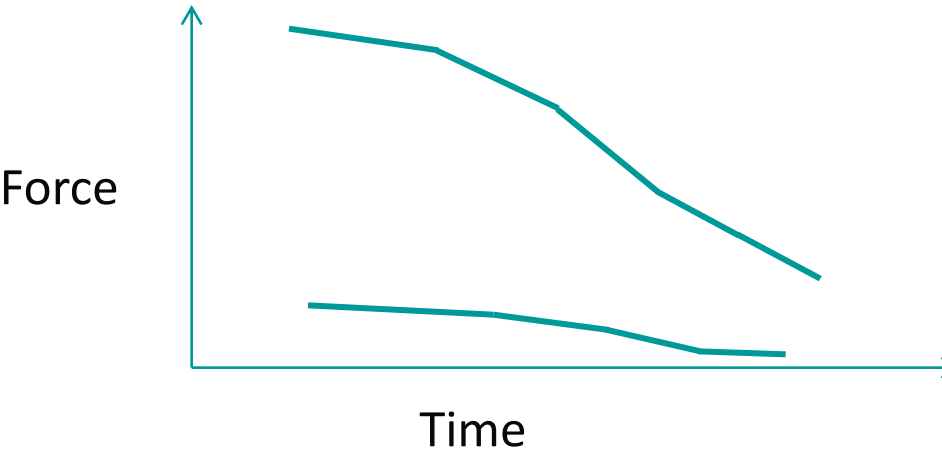
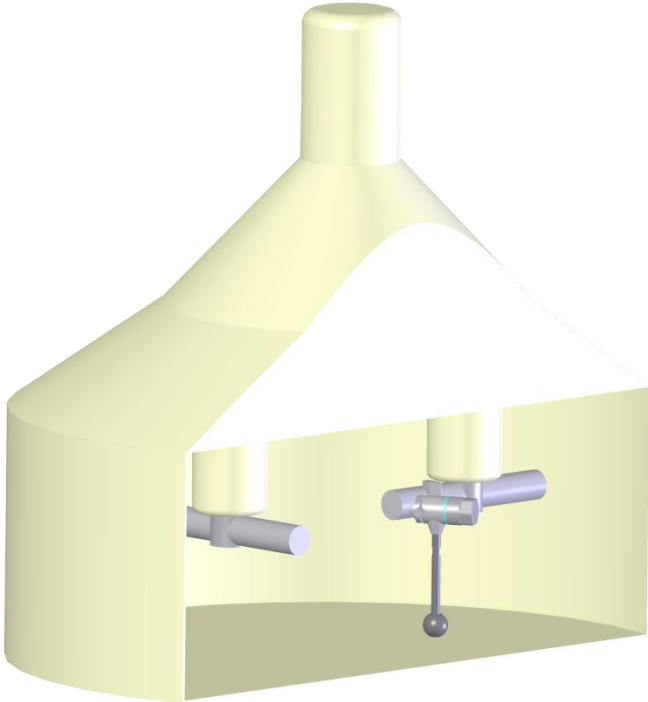
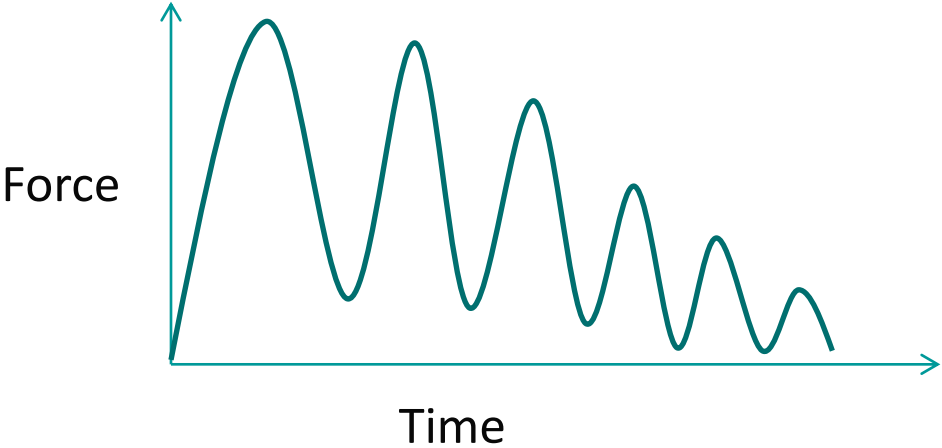
# Visco Probe



# Visco Probe

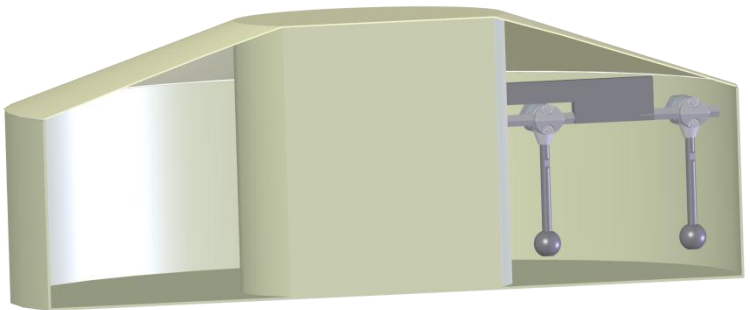
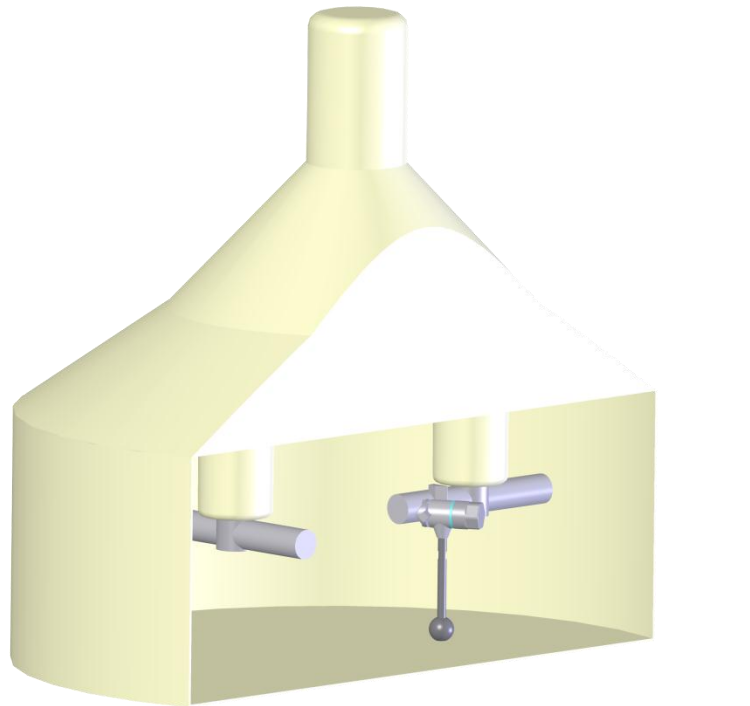
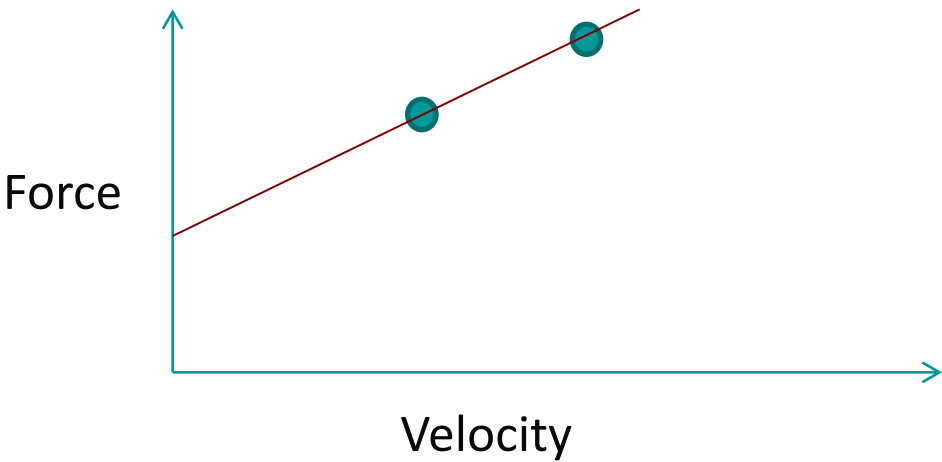
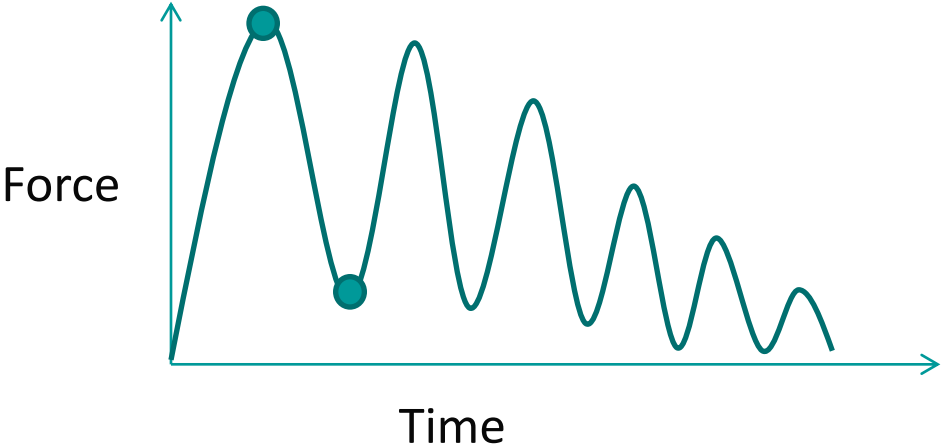


# Visco Probe

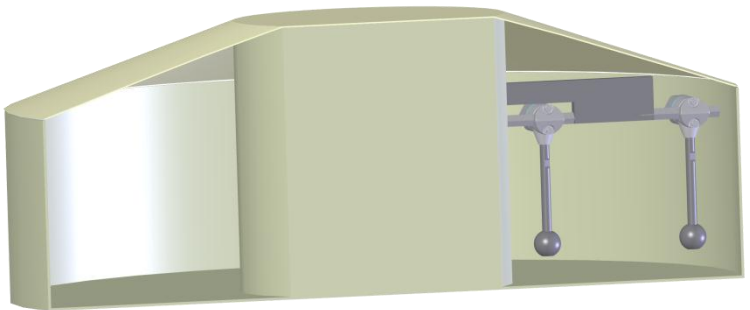
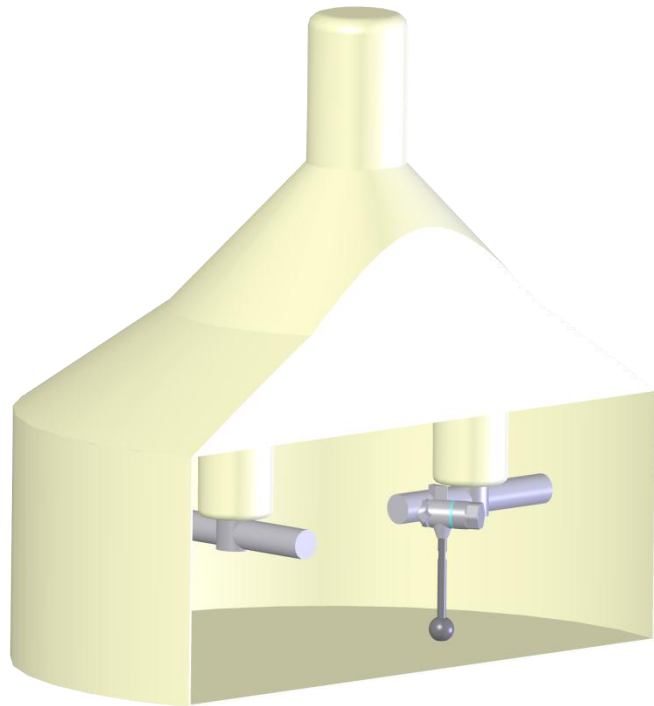
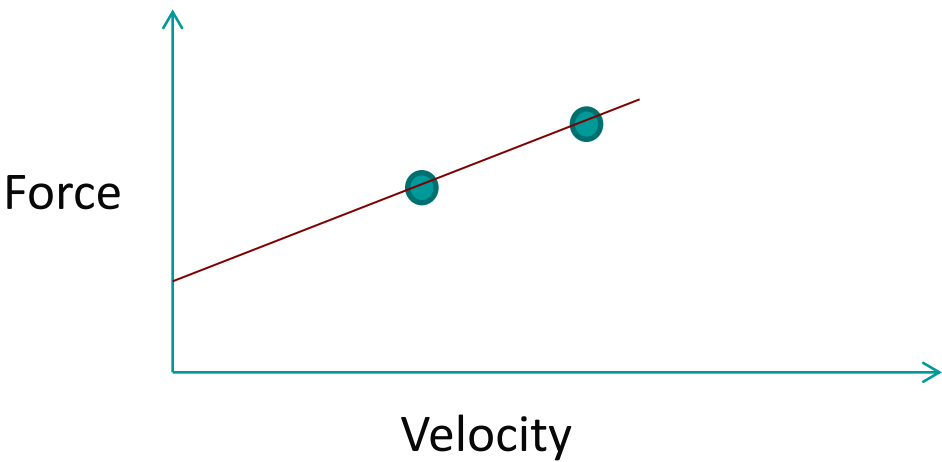
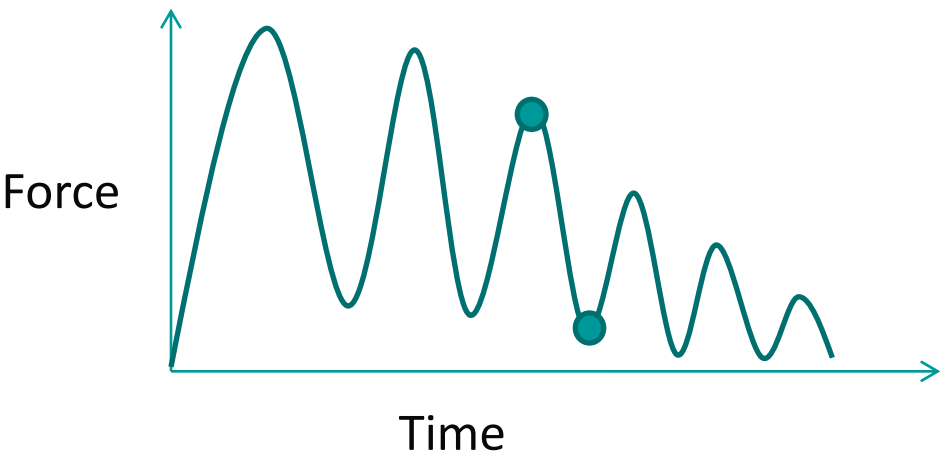




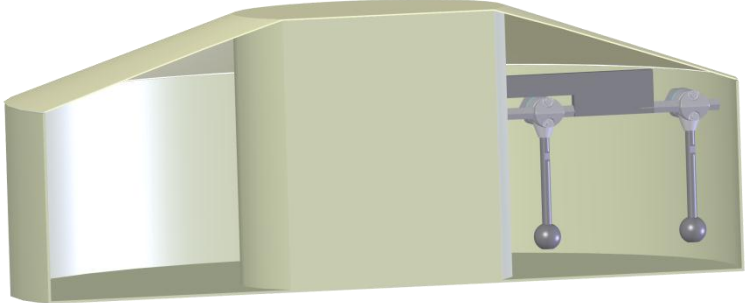
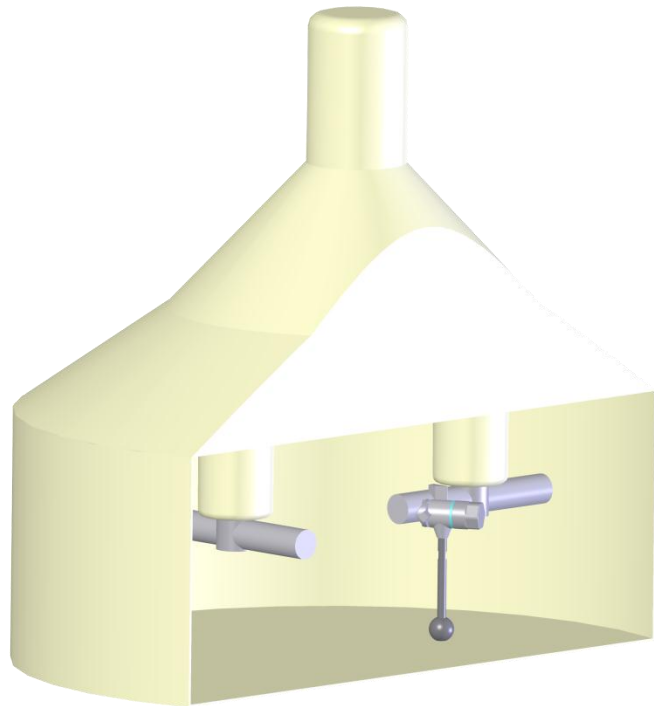
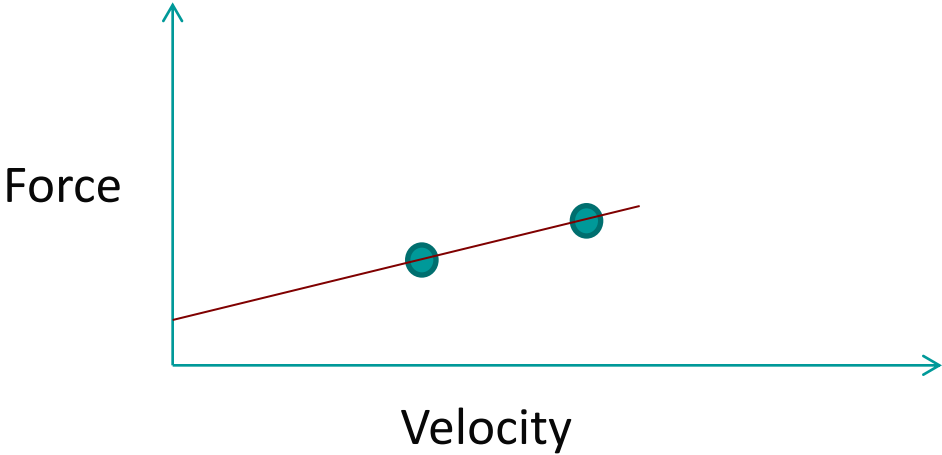
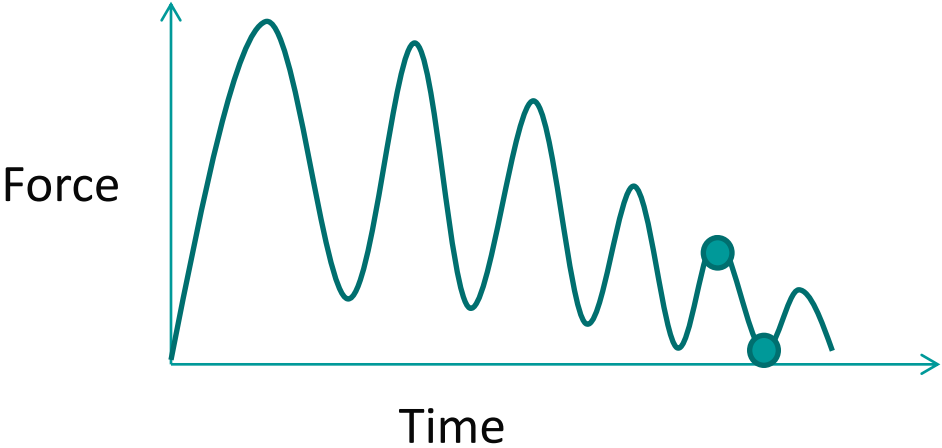
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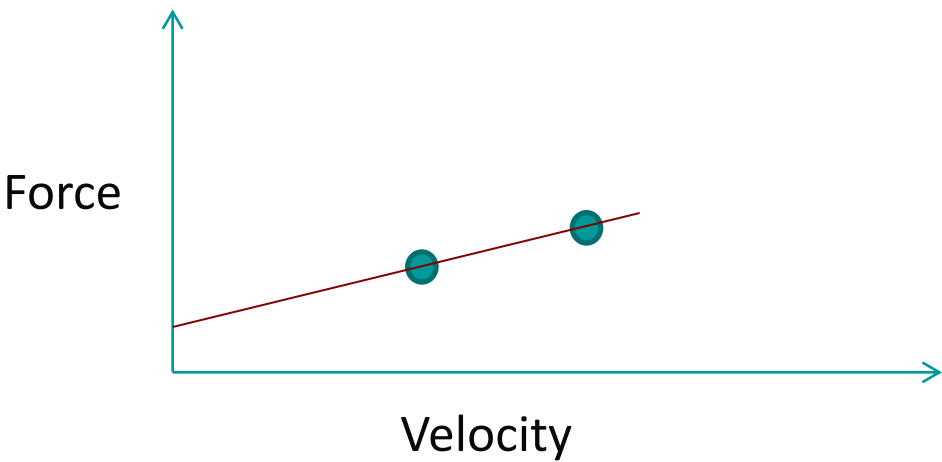
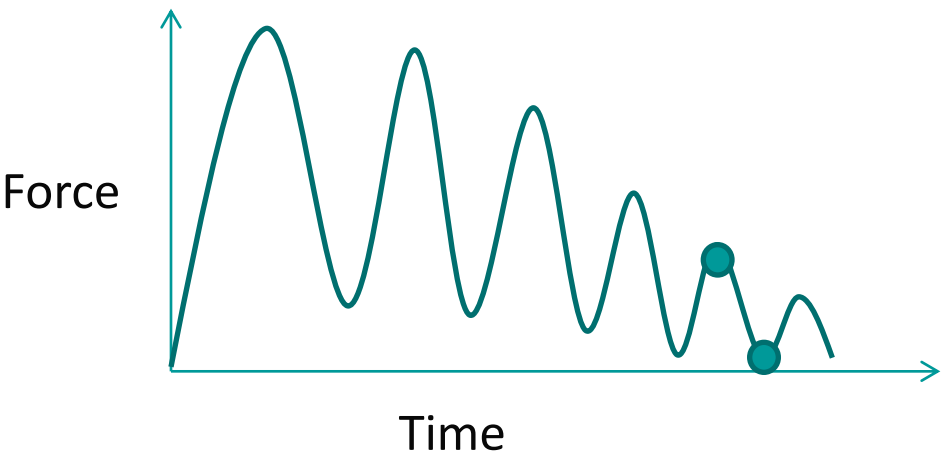
# Visco Probe



# Visco Probe



# Visco Probe



## Visco Probe 1

**Produktübersicht**

Die auf dem Rührwerk montierte Sonde misst und überträgt die Werte über Radiosignal.

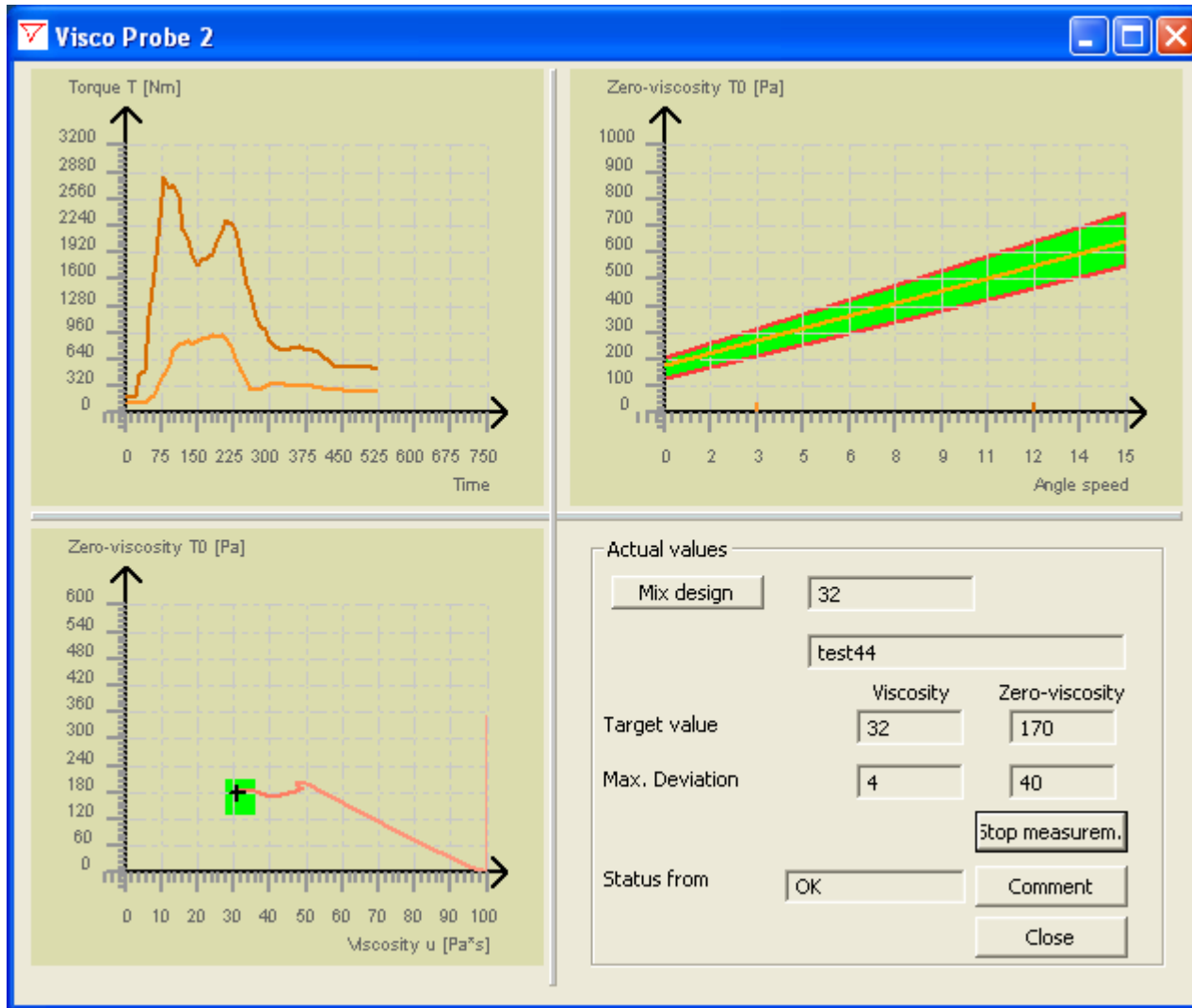
VP1S – Für Gegenstrommischer.

VP1D – Für Ringtrommischer.

Die außen auf dem Mischer montierte Base empfängt die Radiosignale von der Sonde und überträgt die Messdaten über Kabel an einen PC.

Der PC loggt die gemessenen Werte und zeigt sie in einer leichtverständlichen, nutzerfreundlichen und überschaubaren Form an.

# Visco Probe



# Visco Probe

## QC issues:

- The Visco Probe is measuring during the mixing process
- The Visco Probe is measuring in the full batch
- The measured values are related to shear force in the concrete
- All shear forces measured are saved in a log file. It gives the possibility to simulate and analyse batches after casting
- The Visco Probe gives a full documentation of the adjustment of the Visco Probe viscosity and yield value as shown below

### Visco probe

Sats	Dos. Vand		Viskositet				Flydespænding			
	Ønsket	Opnået	Ønsket	Grov	Fin	Slut	Ønsket	Grov	Fin	Slut
1	10,08	10,60	36,00	52,00	33,00	35,00	300,00	358,00	330,00	300,00
Efterløb	2,00		Korrektion pr. enhed (Pr.m <sup>3</sup> )				0,7200			

### In English

Batch	Water		Viscosity				Yield value			
	Target	Added	Target	Measure	1. contr.*	2. contr.*	Target	Measure	1 contr.	2. contr.
1	10,08	10,60	36	52	33	35	300	358	330	300

Tailing: 2,0

Correction per unit per m<sub>3</sub>: 0,722

\* 1. control: At end of mixing time

\* 2. control: When discharging the mixer

# 4C-Rheometer



# 4C-Rheometer



**Rheo Avi Analysis**

Video Analysis

REANALYSE MOVIE

Preview Analysis Setup

START ANALYSIS

Results

Time (s)	Slump Flow (mm)
0	180
5	450
10	550
20	592
40	592

Density  Yield Stress  Pa

Manual Slump Flow  mm Plastic Viscosity  Pa\*s

Slump Flow  mm

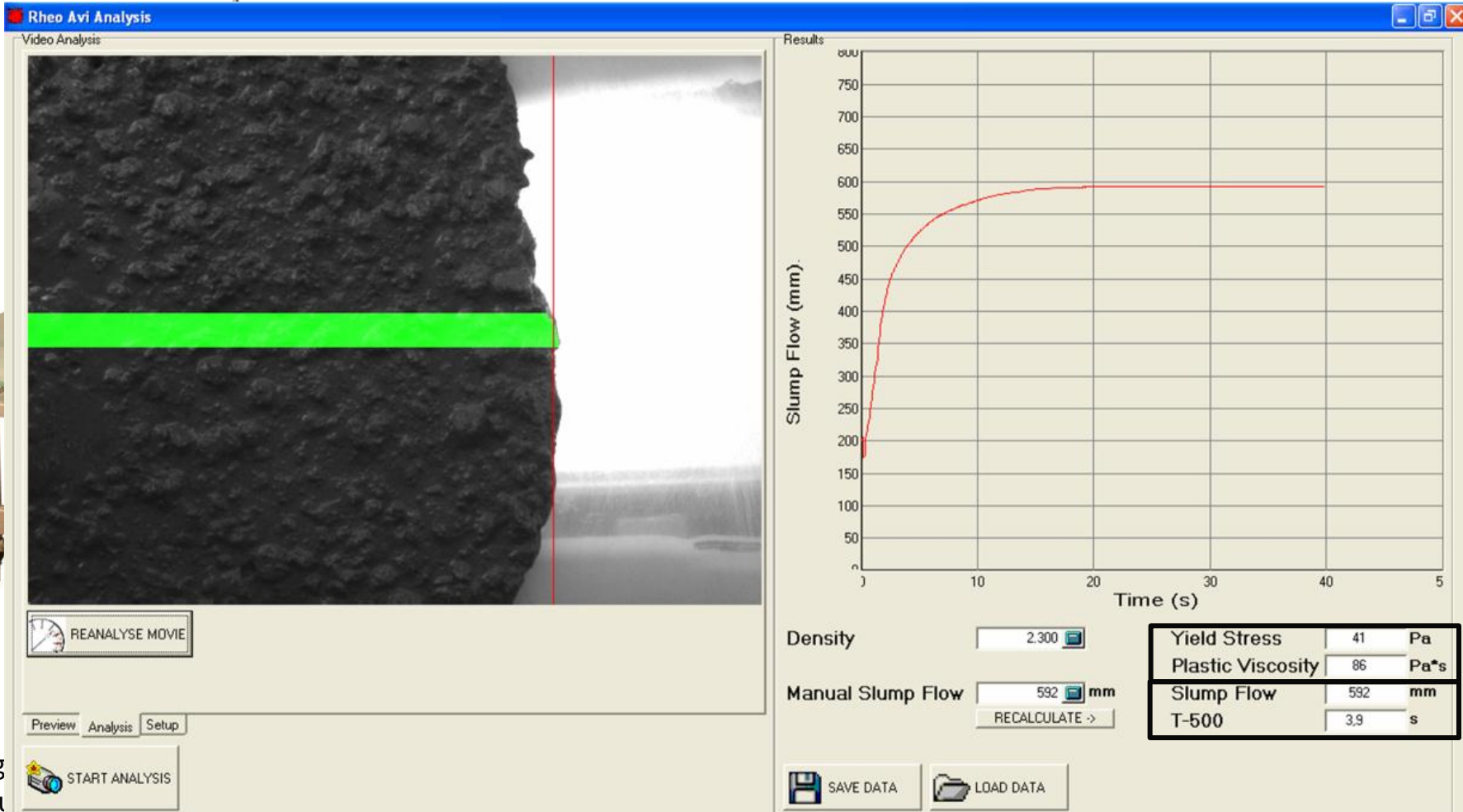
T-500  s

RECALCULATE ->

SAVE DATA LOAD DATA



# 4C-Rheometer



# 4C-Rheometer



# Test program

Two days test program at CRH facilities in Hobro, Jutland. SCC is the only concrete type used to produce prefab prestressed concrete elements of various kind.



# Test program

Mixer type: Haarup 3000 Litres



# Test program

Approximately 30-40 batches produced every day.

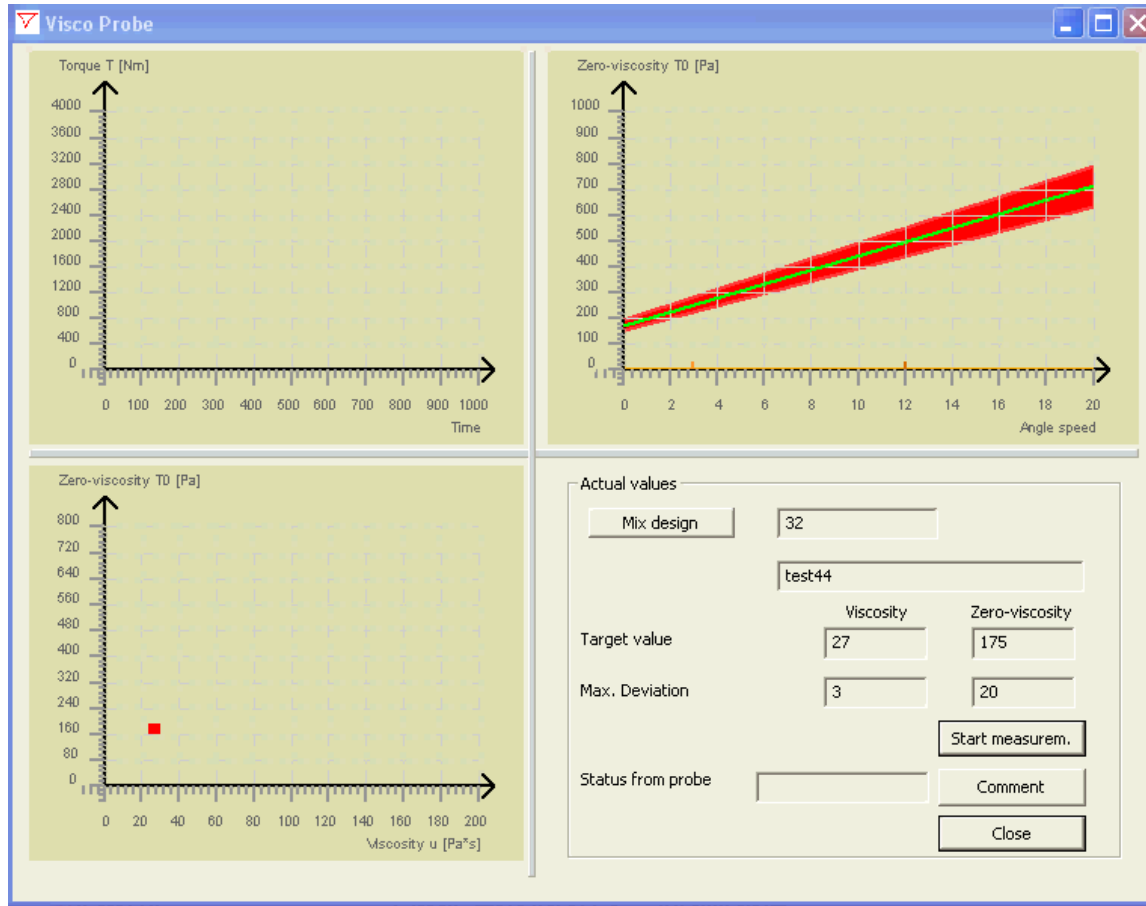


# Test program

Action	App. Time (min)
Mixing	0-3
Visco Probe measurements	0-3
Concrete is emptied into a large crane bucket and transported to the production hall	3-5
A concrete sample is taken from the crane bucket by pouring into a wheel barrow.	5-8
4C-Rheometer measurements	8-10

# Results

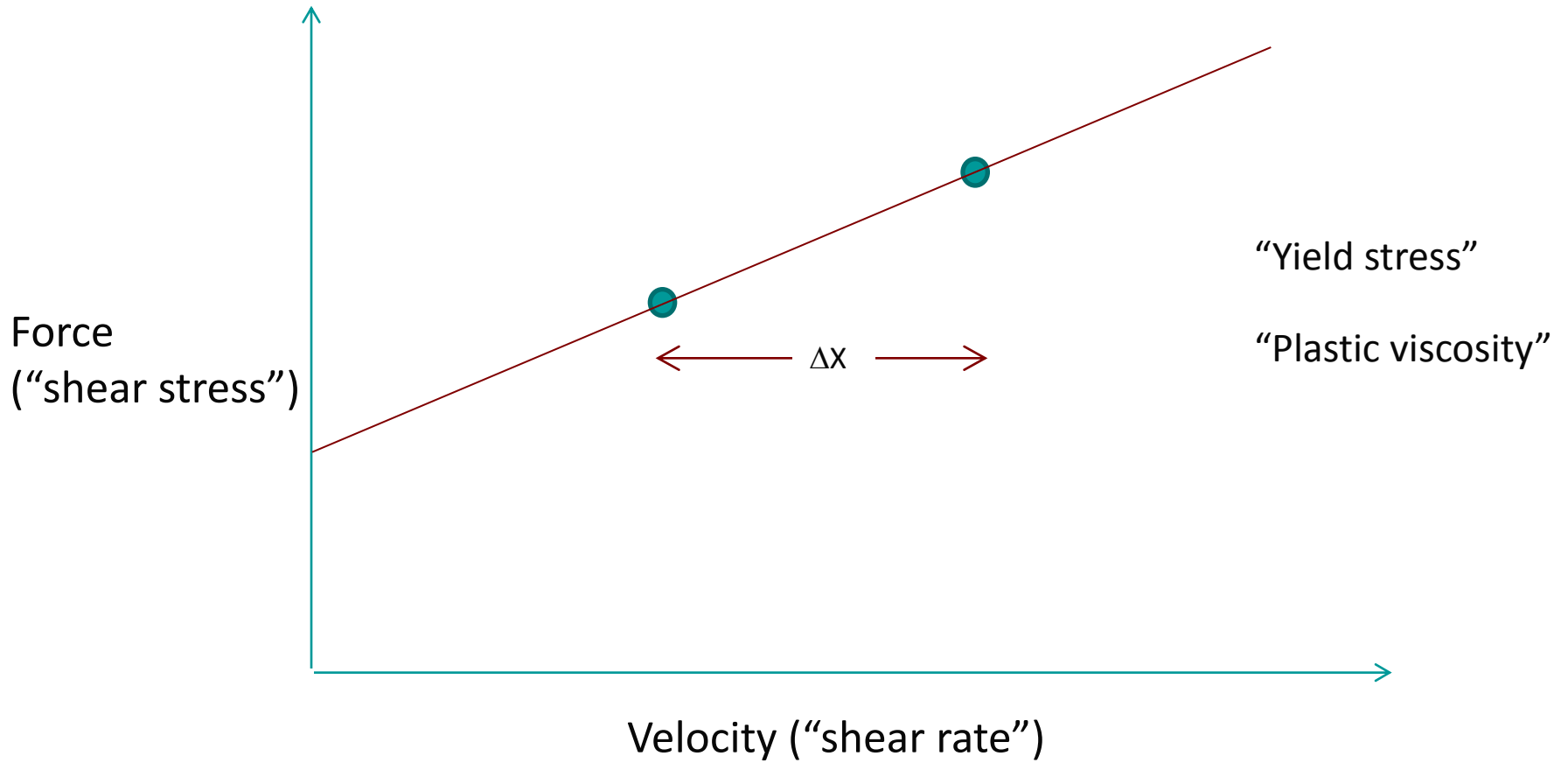
Force  
("shear stress")



Velocity ("shear rate")

# Results

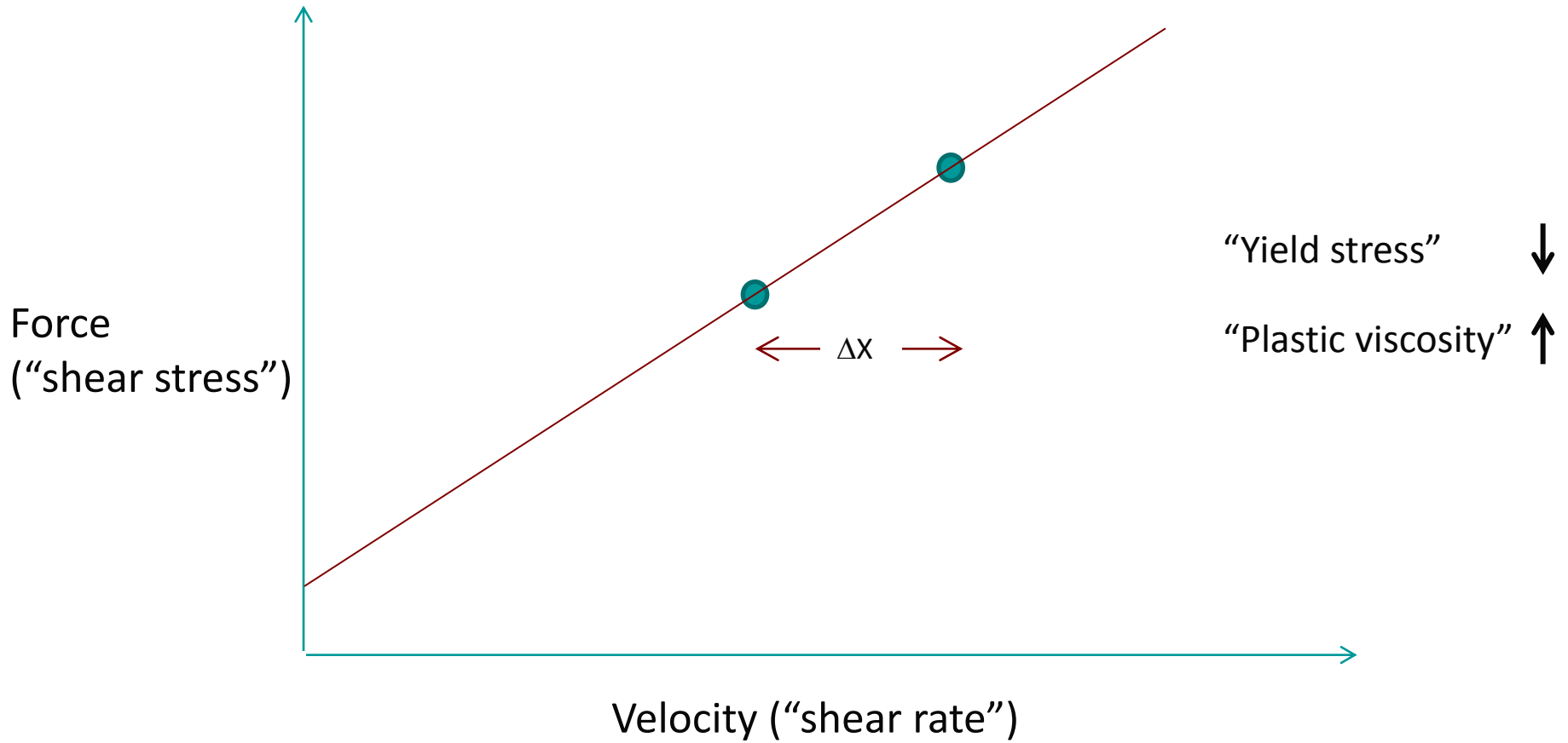
Visco Probe – adjustment of parameters





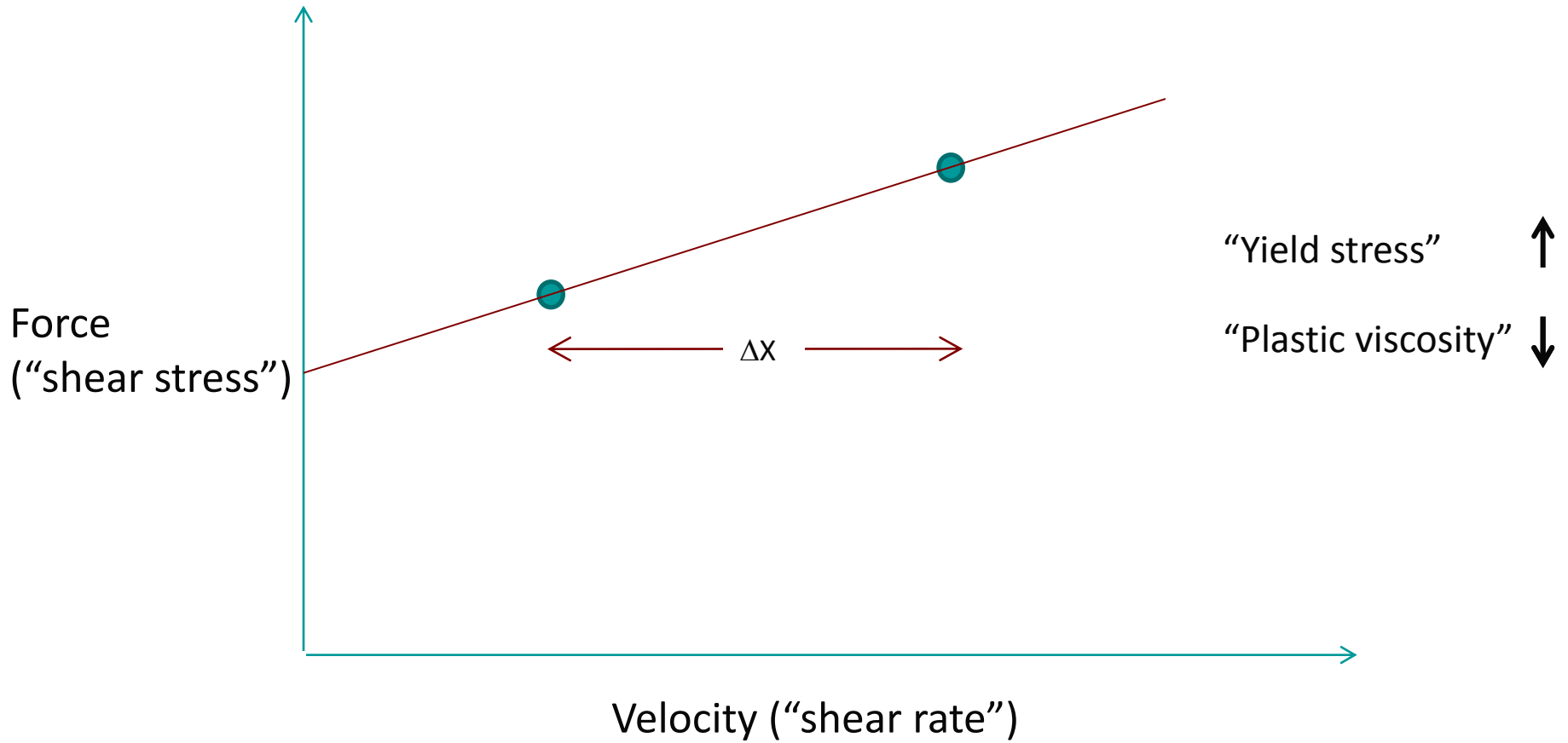
# Results

Visco Probe – adjustment of parameters



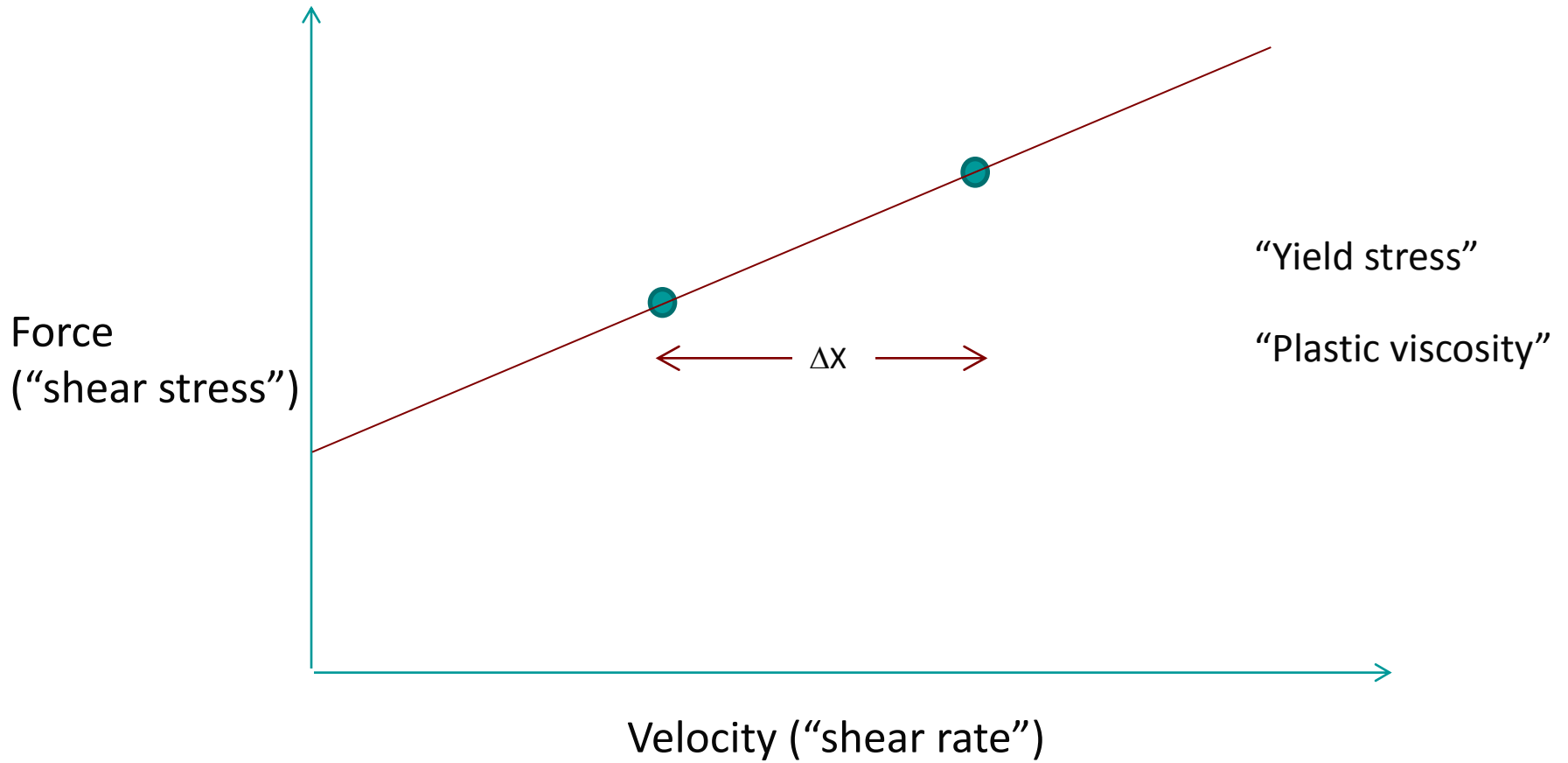
# Results

Visco Probe – adjustment of parameters



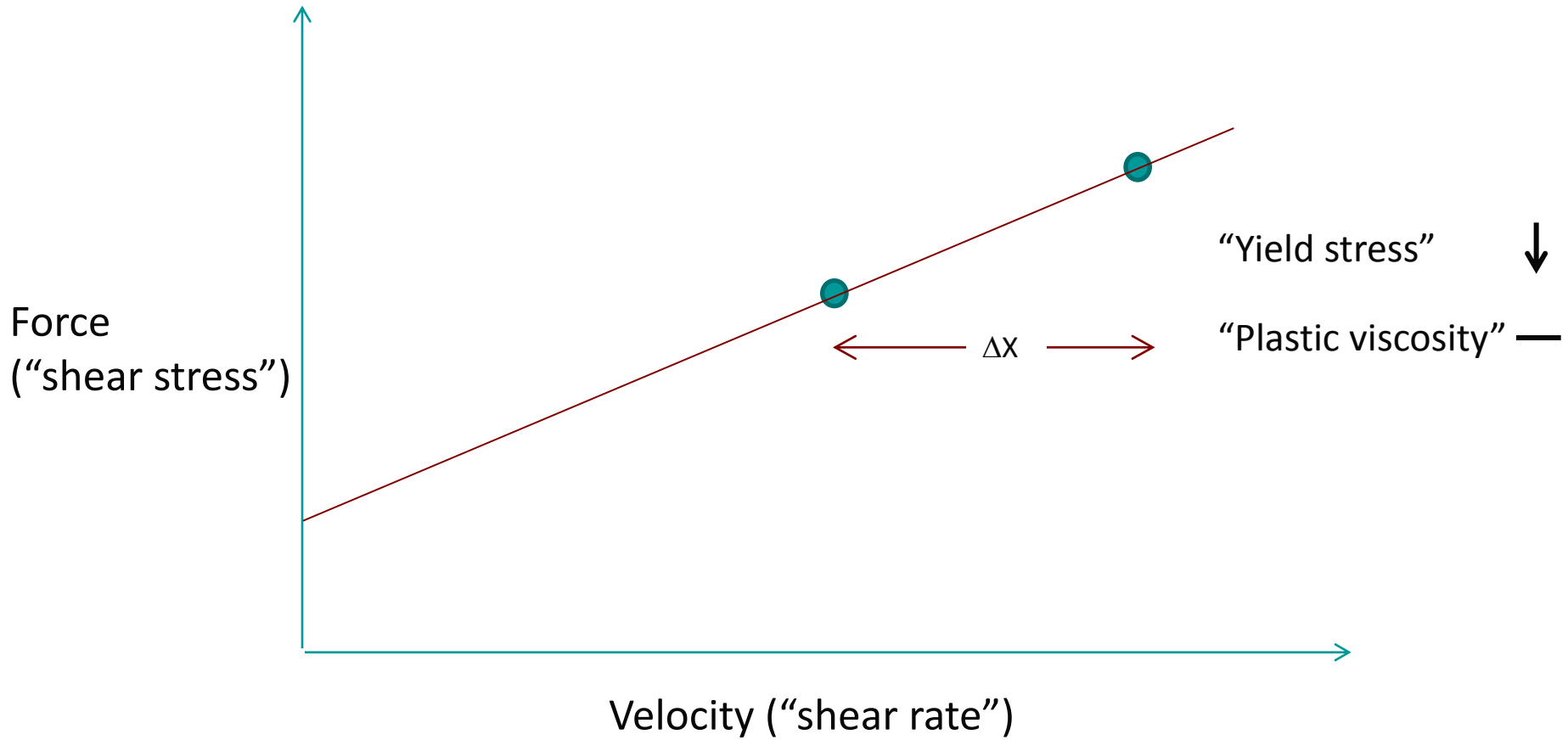
# Results

Visco Probe – adjustment of parameters



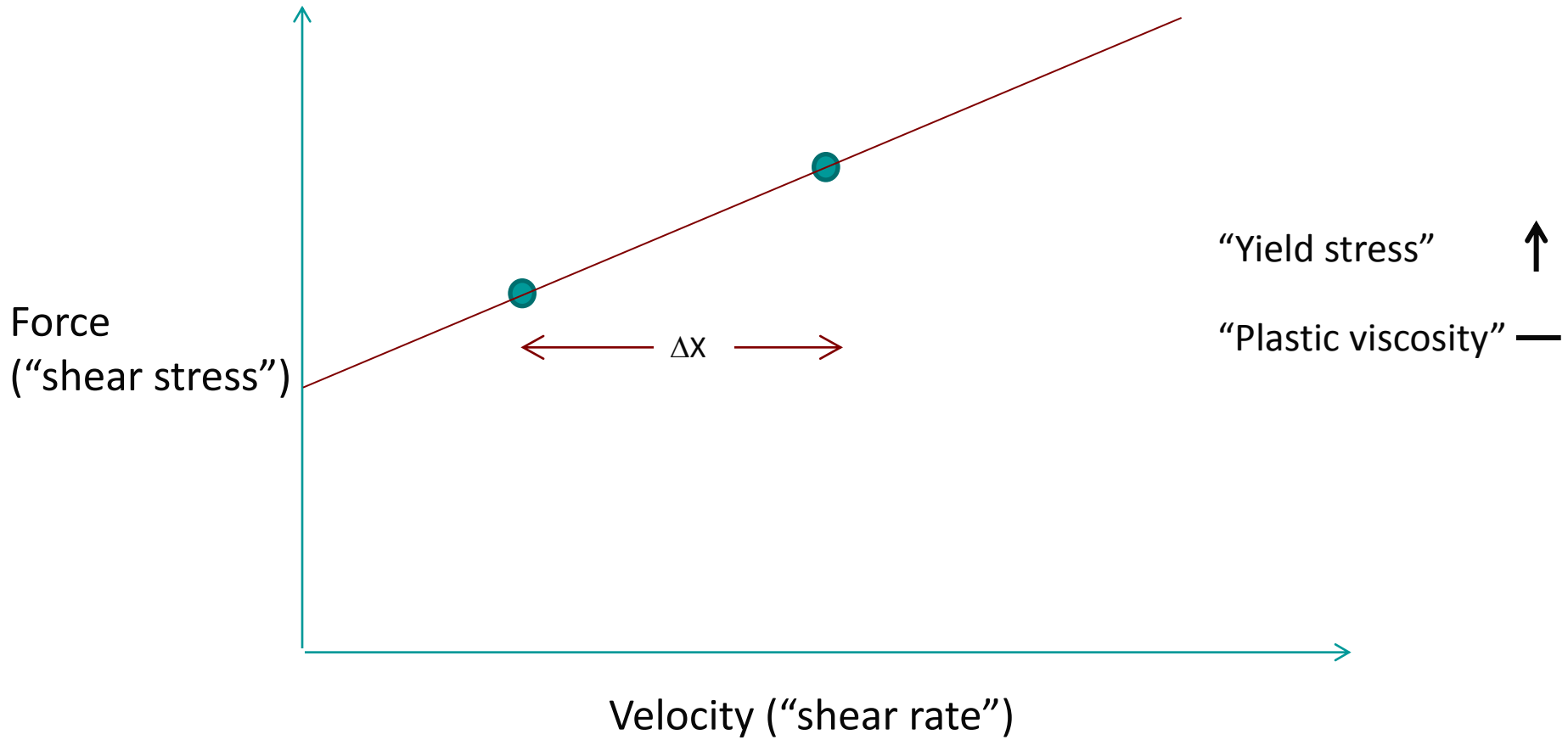
# Result

Visco Probe – adjustment of parameters

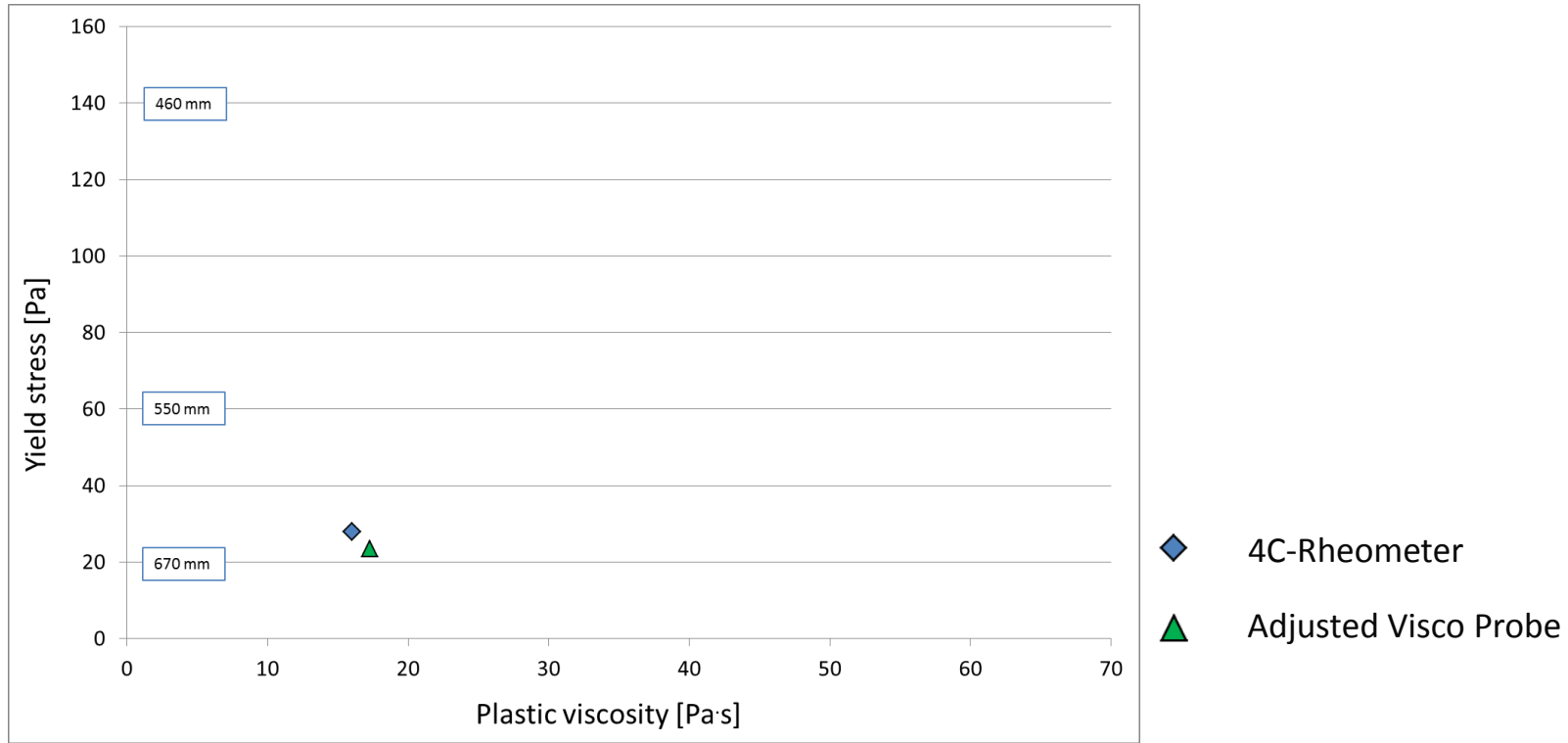


# Results

Visco Probe – adjustment of parameters

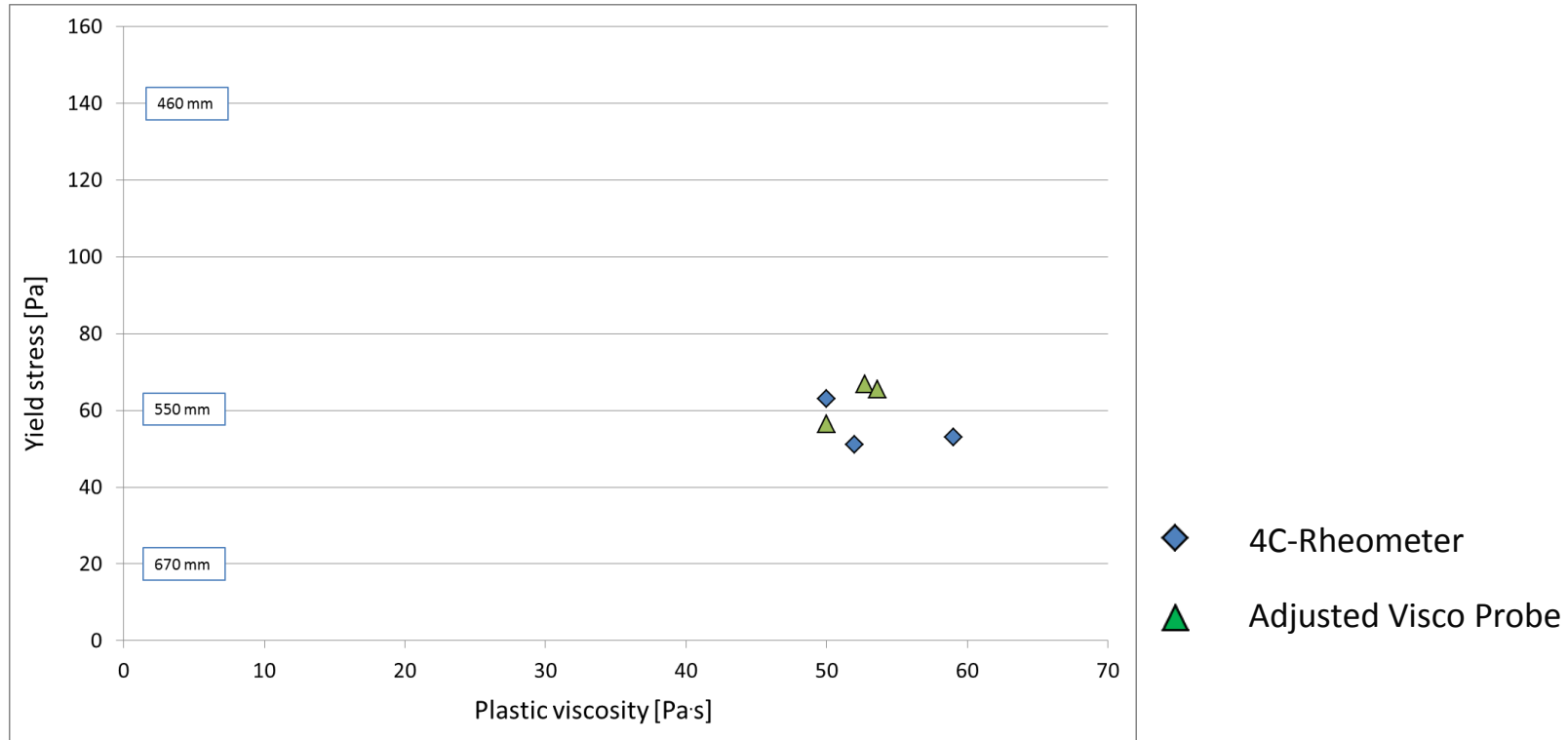


# Results



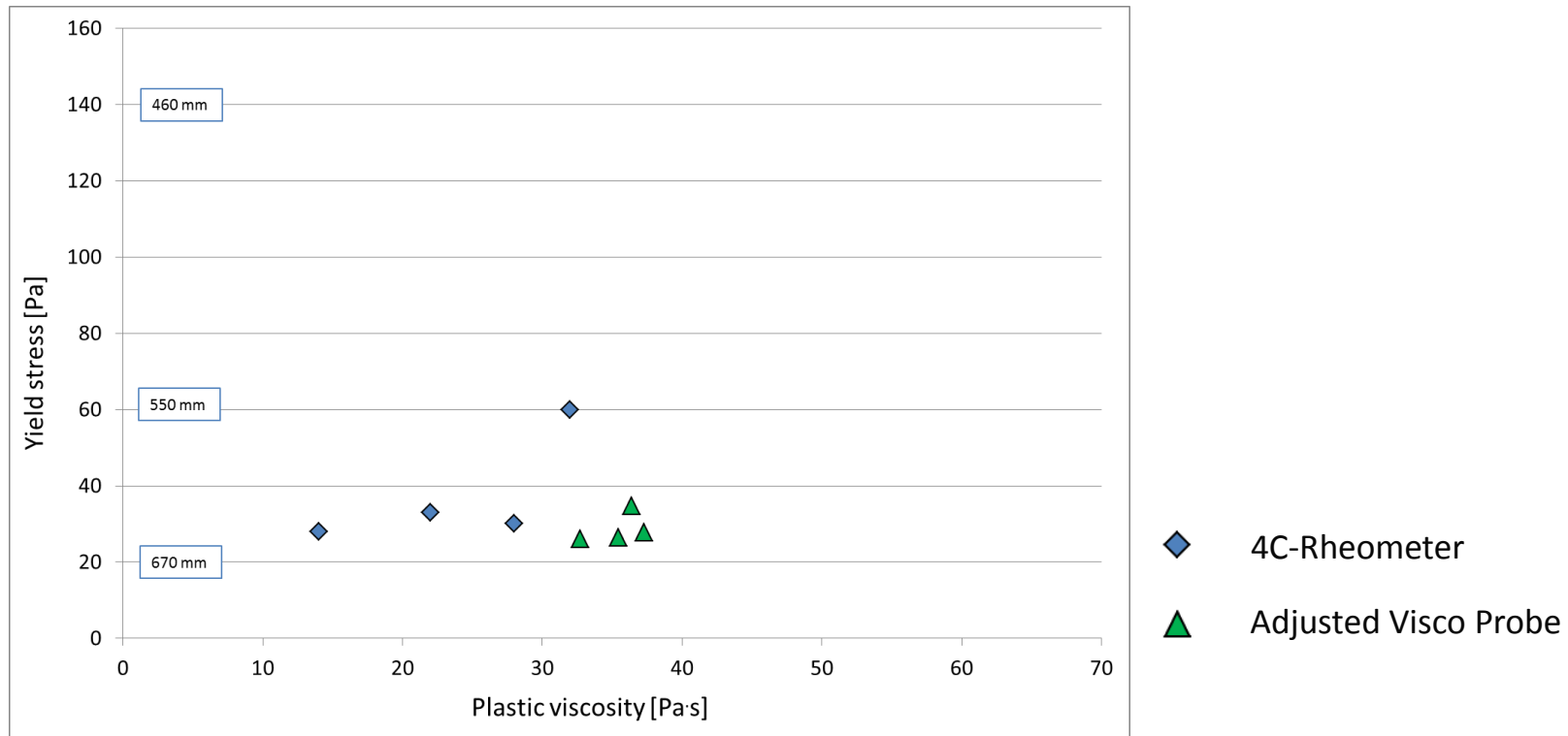
Mix design no. 39

# Results



Mix design no. 50

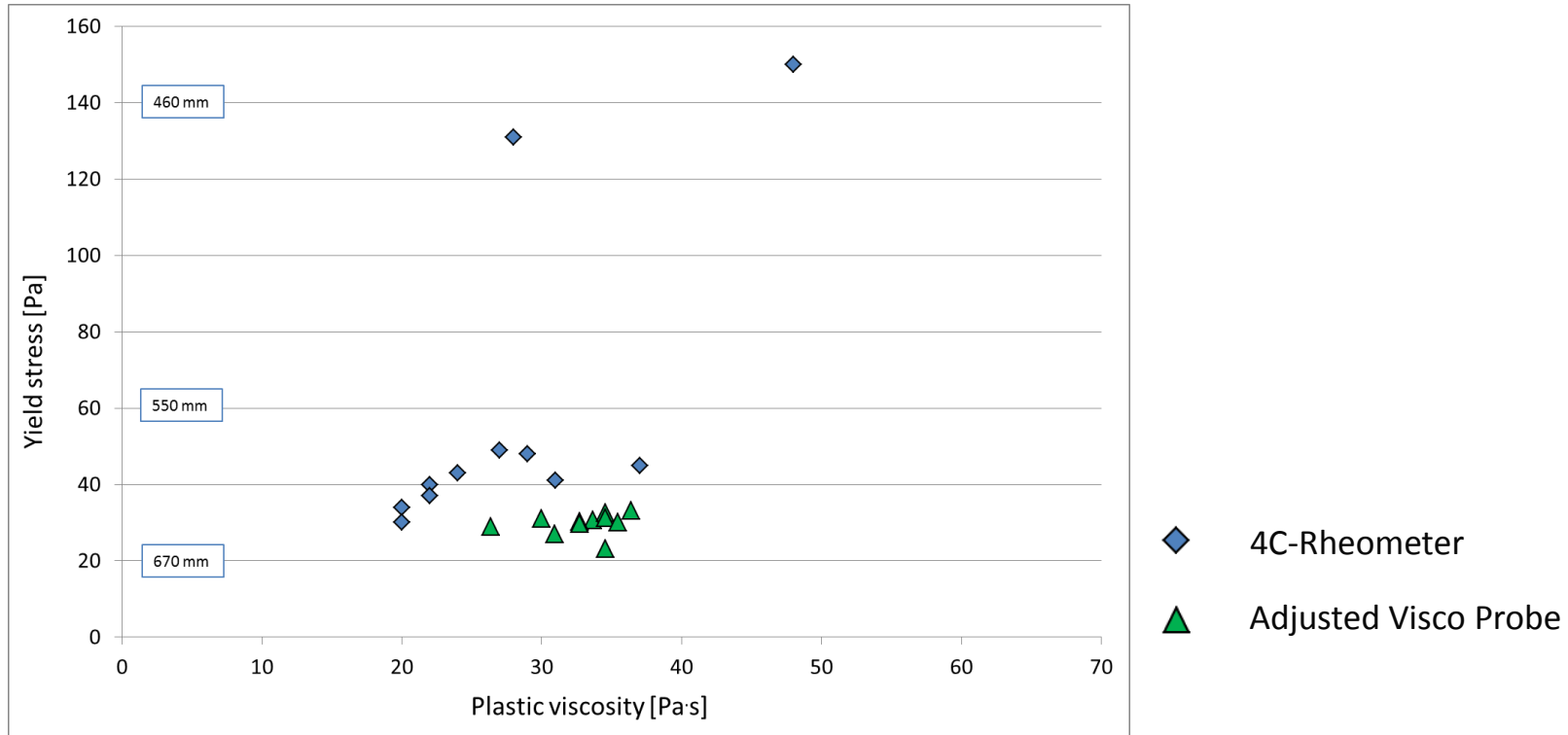
# Results



Mix design no. 63

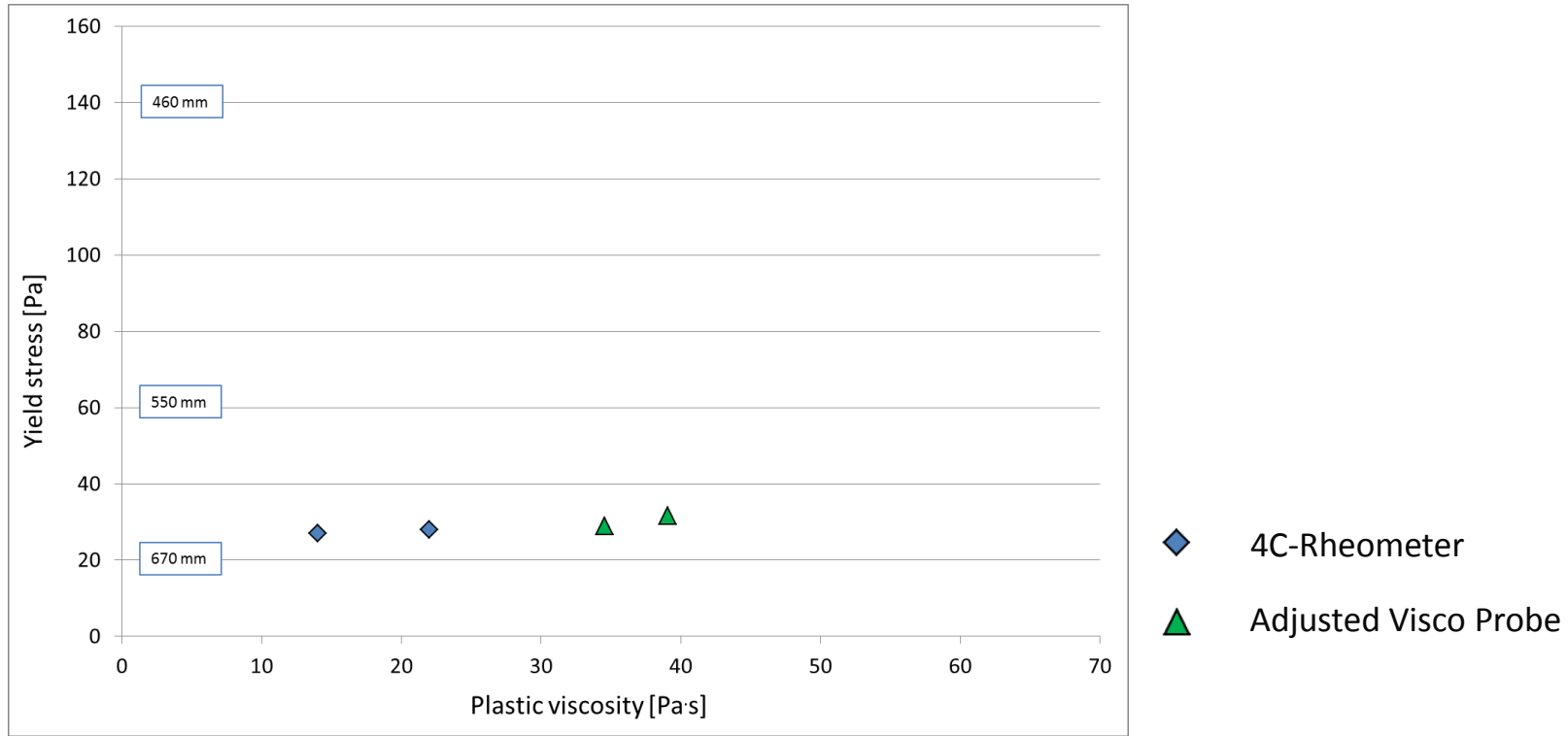


# Results



Mix design no. 67

# Results



Mix design no. 70

# Conclusion

A comparative study of corresponding Visco Probe and 4C-Rheometer measurements have been carried out.

A total of 21 SCC mixes have been measured. The concretes were produced at Betonelement in a full scale counter current mixer.

Arbitrary values of “plastic viscosity” and “yield stress” from the Visco Probe have been correlated to physical rheological parameters measured by the 4C-Rheometer. The same best fit optimisation have been applied on all measurements.

A reasonable correlation is obtained on the plastic viscosity and yield stress. Both within the same mix design series and across mix designs.

# Conclusion

However, a deviation was observed on two of the measurements of a very high yield stress measured by the 4C-Rheometer. Further investigations are needed to explain these “off” values. Potential reasons:

- It is a “source of error” due to practical setup.
- The flow in the mixer is very complex. Maybe at high yield stresses, the flow pattern changes character, which need to be taken into account e.g. through optimising the position of the Visco Probe inside the mixer.

Similar kind of studies are on-going at Hi-Con, producer of concrete elements with high strength concrete, and Unicon, ready-mixed concrete producer.

# Acknowledgement

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## **Partners**

Bekaert, Aalborg Portland, COWI, Unicon, Hi-Con, CRH Concrete, Danish Concrete Element Association, Convi, MT Højgaard, Danish Road Directorate, Technical University of Denmark, Danish Technological Institute

## **Associated partners**

The Danish Construction Association, Confederation of Danish Industry, Rail Net Denmark, Femern

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