



THE INFLUENCE OF ADHESION ON CUTTING PROCESSES IN DREDGING

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Dredging Summit & Expo 2015

INTRODUCTION

GREAT LAKES DREDGE & DOCK

- Clamshell Dredge



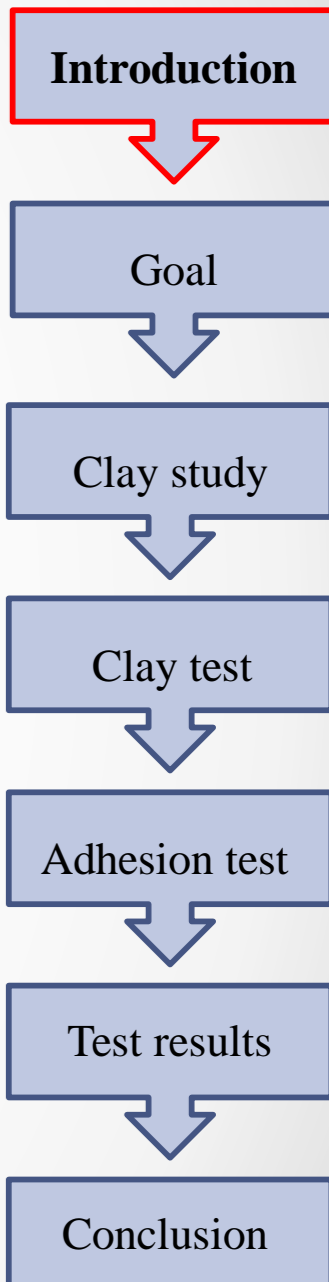
DELFT UNIVERSITY OF TECHNOLOGY

- Literature



TEXAS A&M UNIVERSITY

- Testing facilities



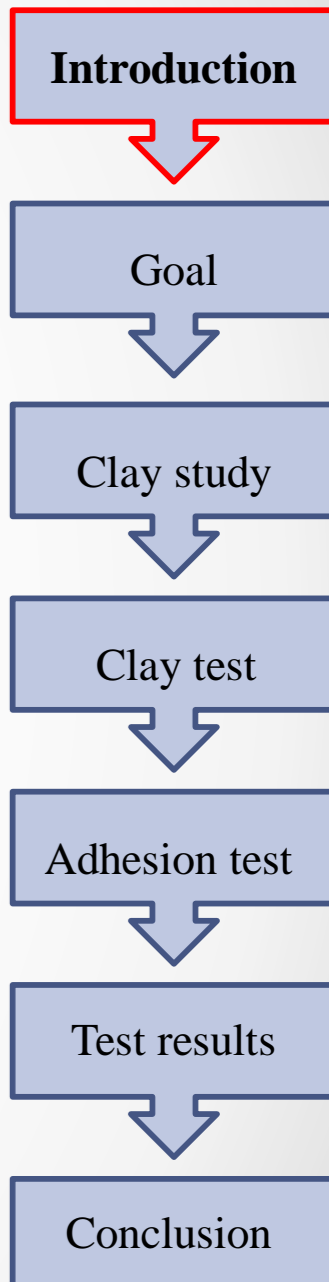
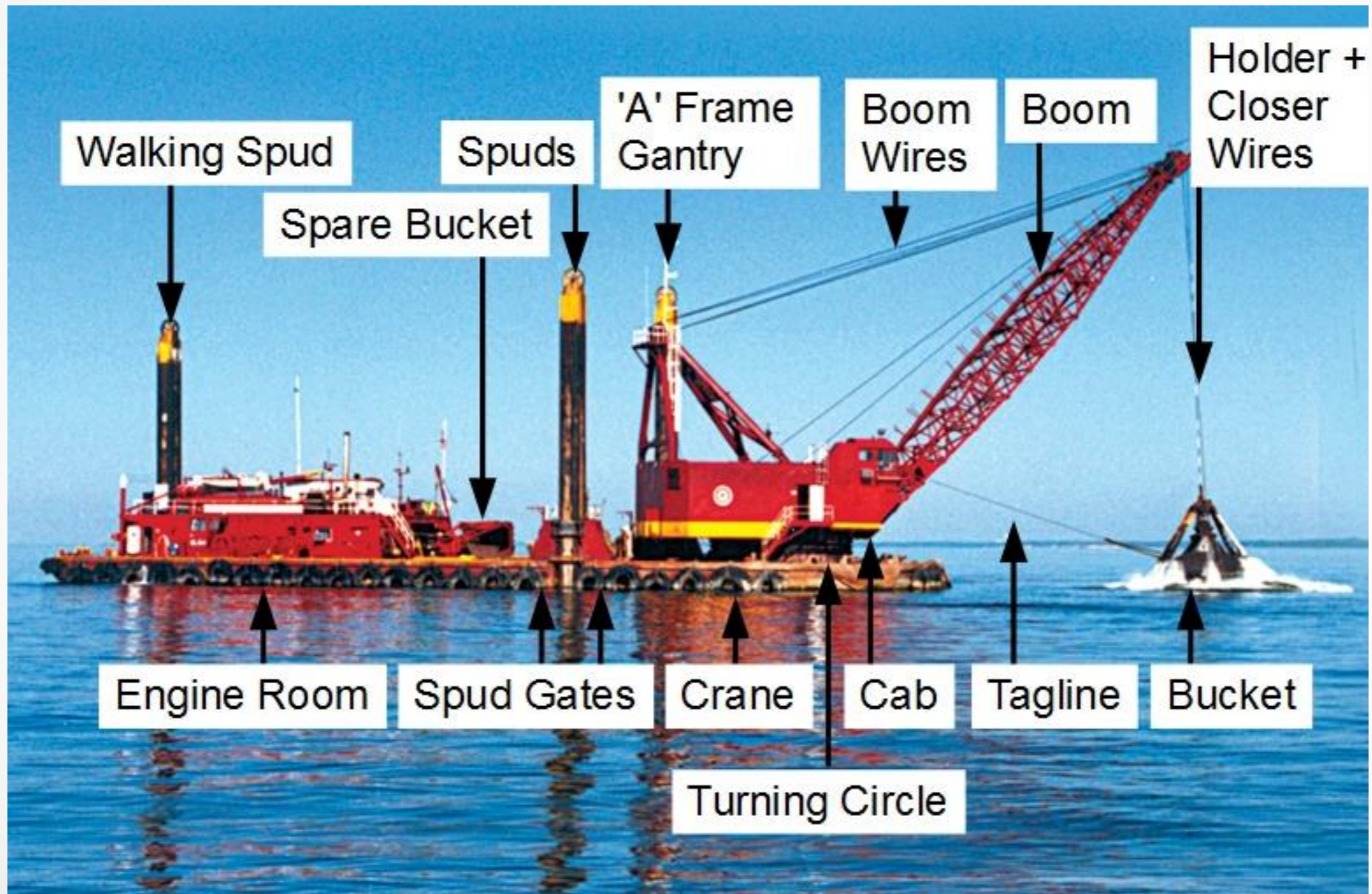
OVERVIEW

1. INTRODUCTION
2. GOAL
3. CLAY STUDY
4. CLAY TEST
5. ADHESIVE TEST
6. TEST RESULTS
7. CONCLUSION



INTRODUCTION

Clamshell Dredge

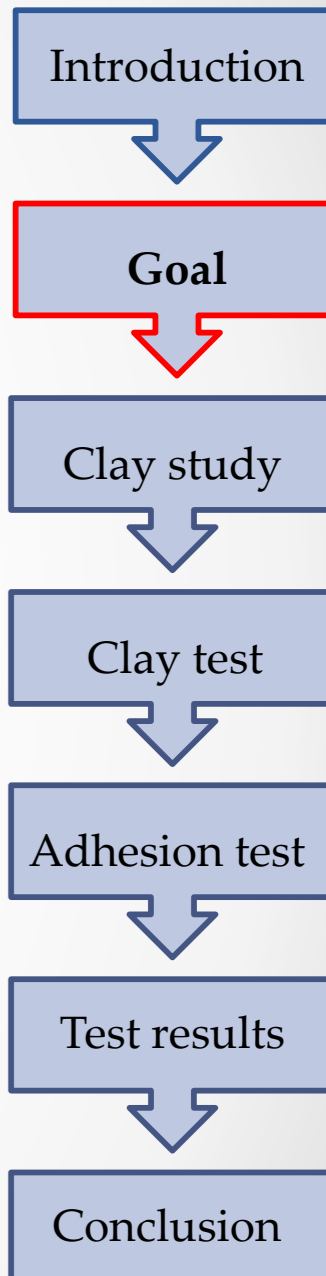


RESEARCH OBJECTIVE

Optimization of the clamshell bucket for cubic meter [m³] production per cycle [s] for stiffer clays

Objective elements:

- Bucket kinematics
- Bucket geometry
- Clay cutting process
 - Cohesion
 - Adhesion
- Clay properties

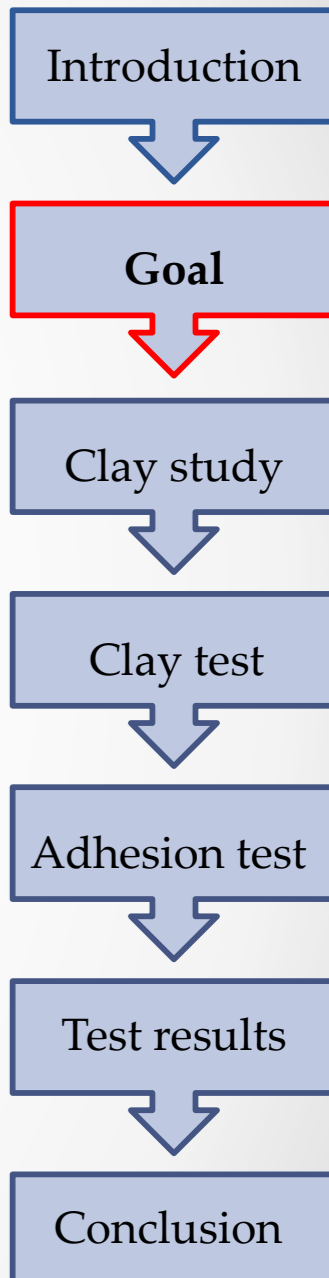


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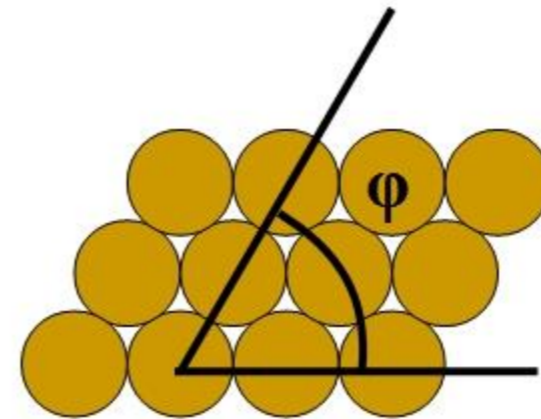
- Bucket kinematics
- Bucket geometry
- Clay cutting process
 - Cohesion
 - **Adhesion**
- Clay properties



BASIC DEFINITION

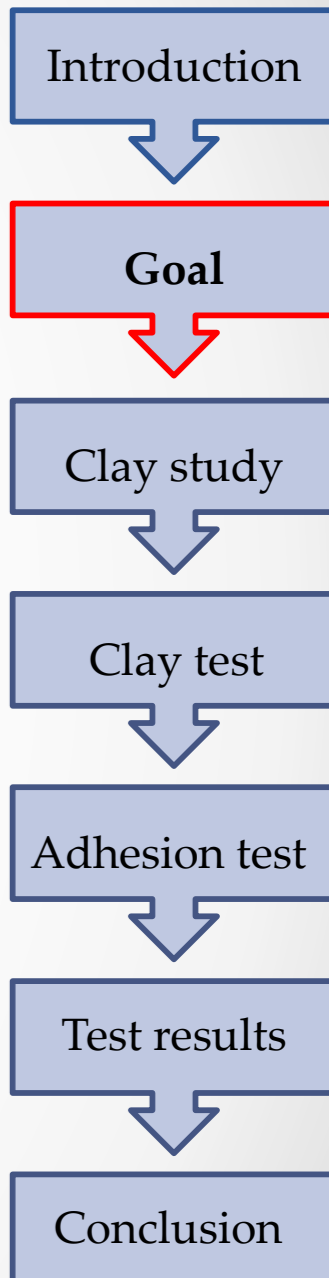
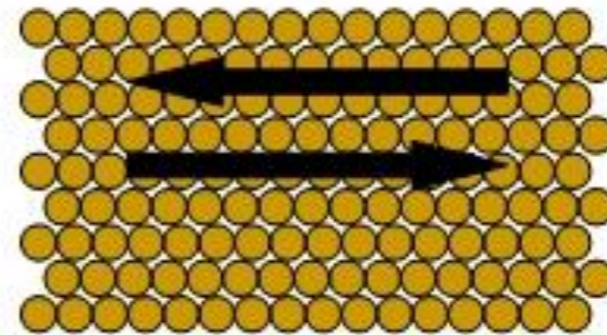
Sand properties

- Particle diameter 0.06-2.0 mm
- Internal friction angle (φ) [degree]
- External friction angle (δ) [degree]



Clay properties

- Particle diameter <0.002 mm
- Cohesion [kPa]
 - Internal shear strength
- Adhesion [kPa]
 - External shear strength



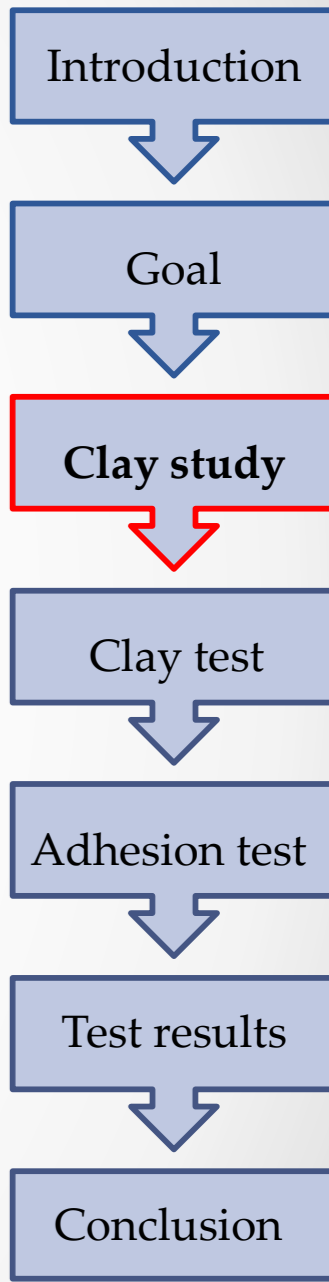
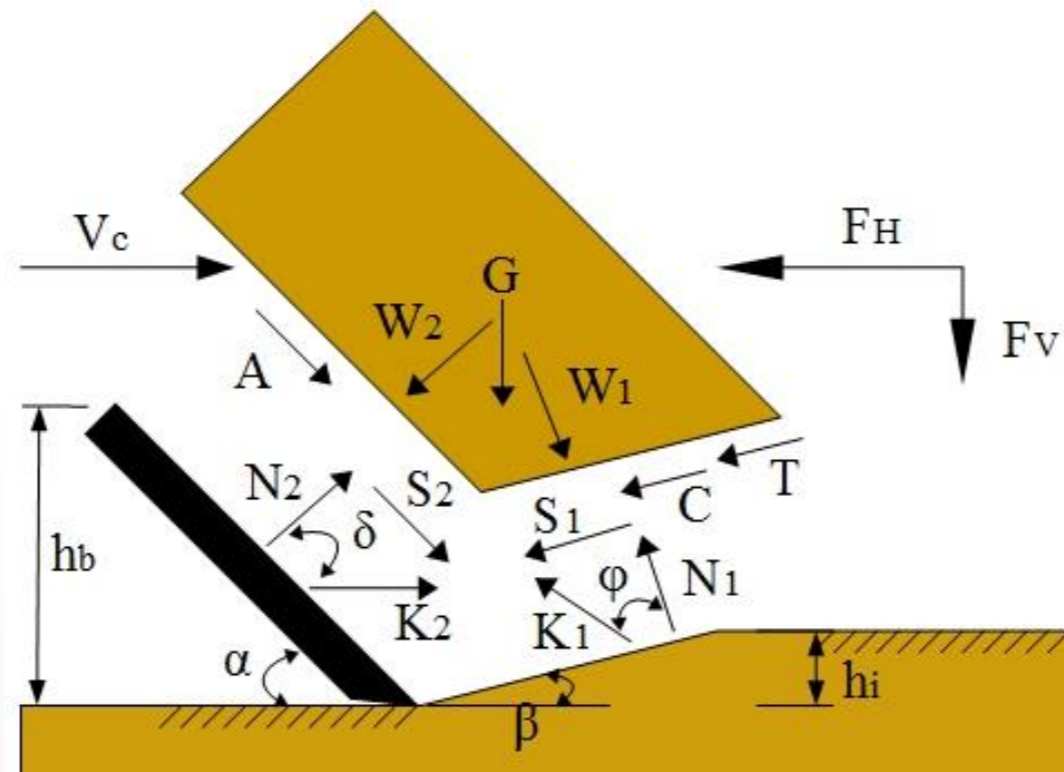
GENERAL CUTTING THEORY

Forces:

$$F_h = -W_2 \cdot \sin(\alpha) + K_2 \cdot \sin(\alpha + \delta) + A \cdot \cos(\alpha)$$

$$F_v = -W_2 \cdot \cos(\alpha) + K_2 \cdot \sin(\alpha + \delta) - A \cdot \sin(\alpha)$$

$$K_2 = \frac{W_2 \cdot \sin(\alpha + \beta + \varphi) + W_1 \cdot \sin(\varphi) + G \cdot \sin(\beta + \varphi) + I \cdot \cos(\varphi) + C \cdot \cos(\varphi) - A \cdot \sin(\alpha + \beta + \varphi)}{\sin(\alpha + \beta + \delta + \varphi)}$$



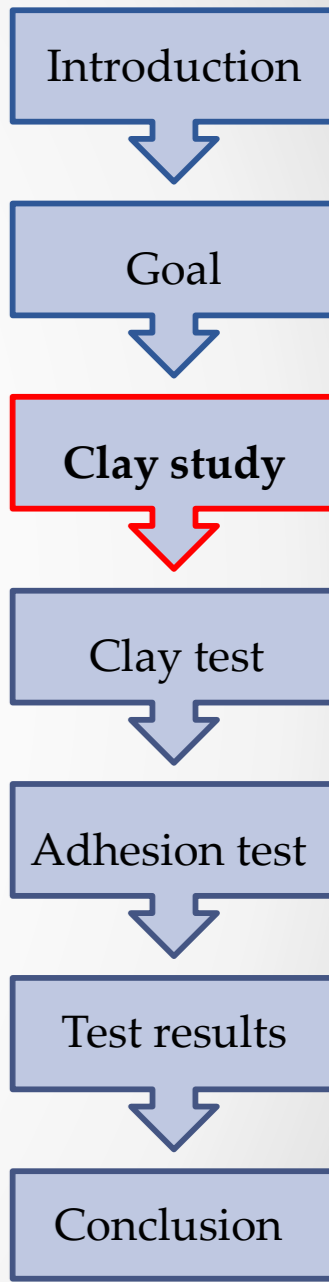
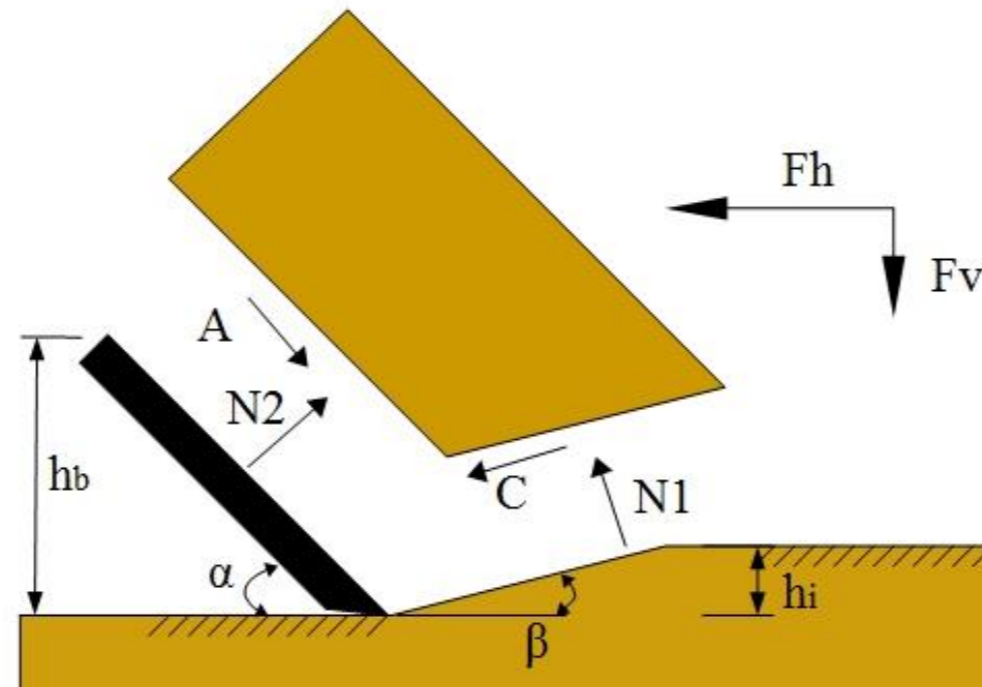
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ADHESIVE EFFECT ON PRODUCTION

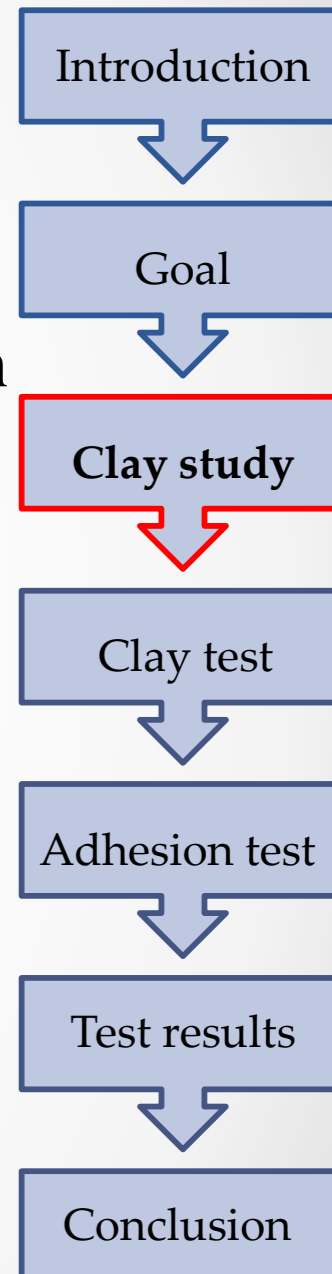
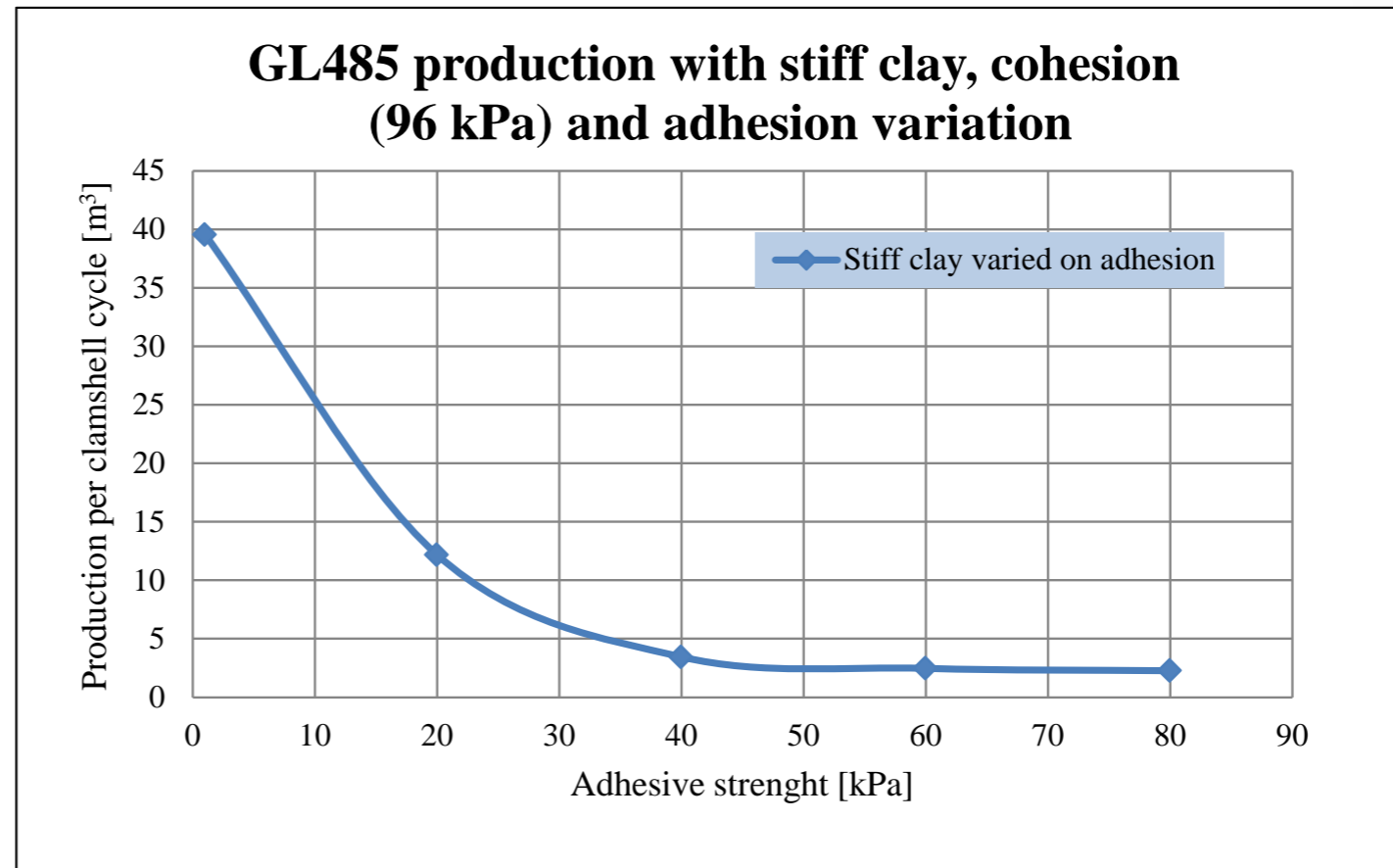
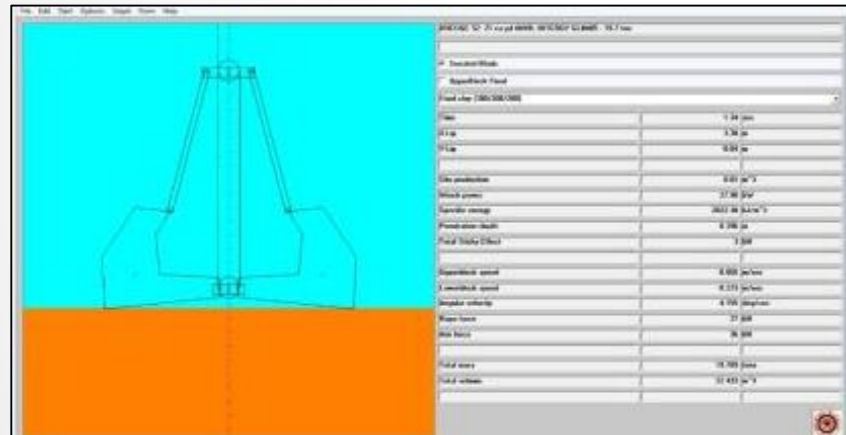
Clamshell Closing Simulation:

GL485 – clamshell bucket

- 16 m³
- 24,6 ton

Clay properties:

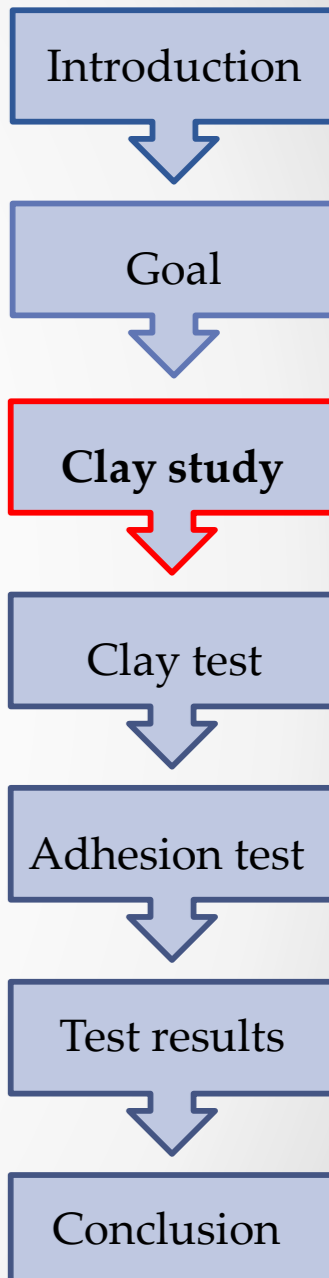
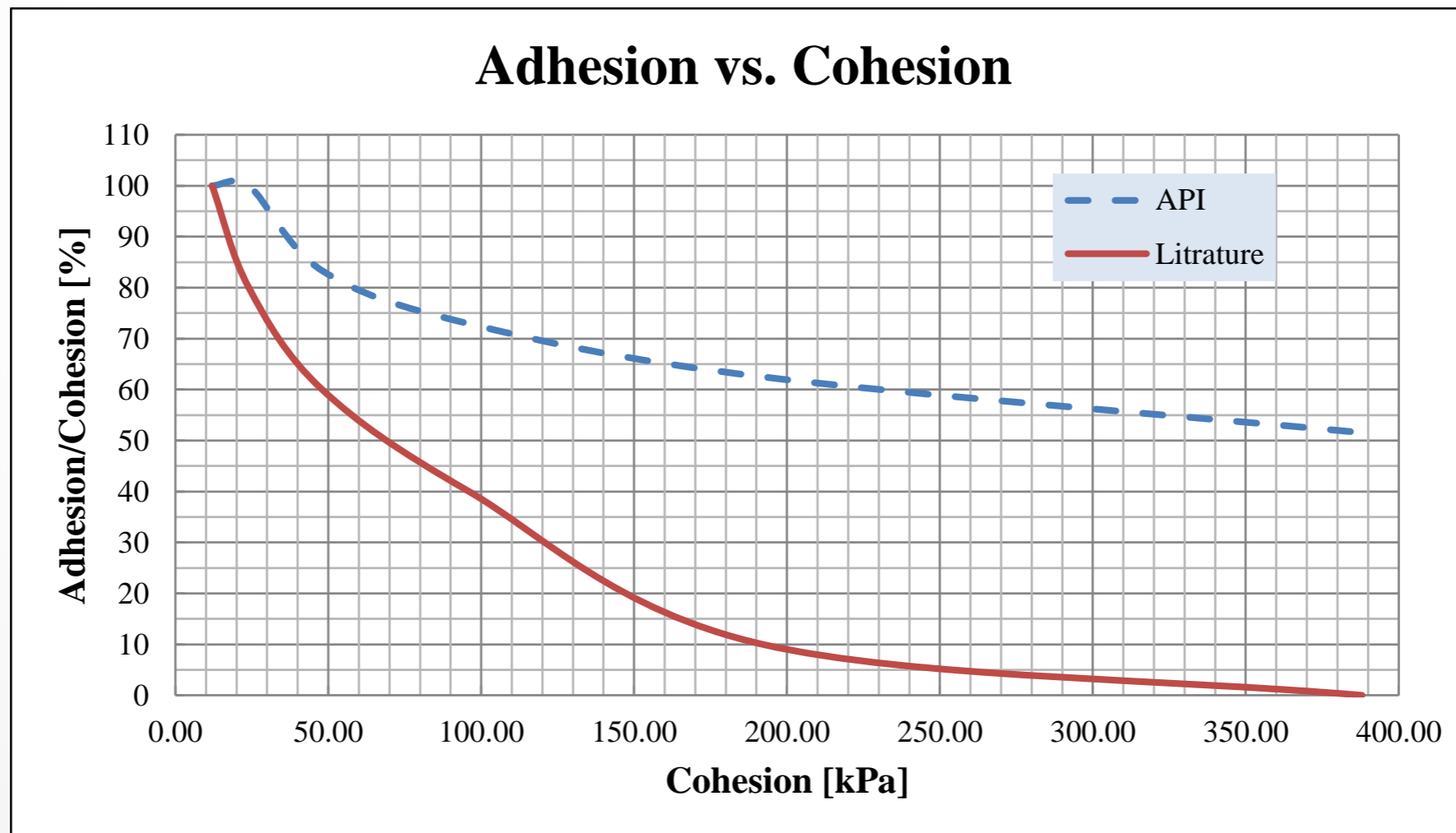
- 96 kPa, stiff clay - cohesive strength
- 1-80 kPa – adhesive strength



CLAY STUDY

Clay properties:

- Cohesive strength [kPa] (internal shear strength)
- Adhesion strength [kPa] (extranal shear strength)



NATURAL FIELD CLAYS

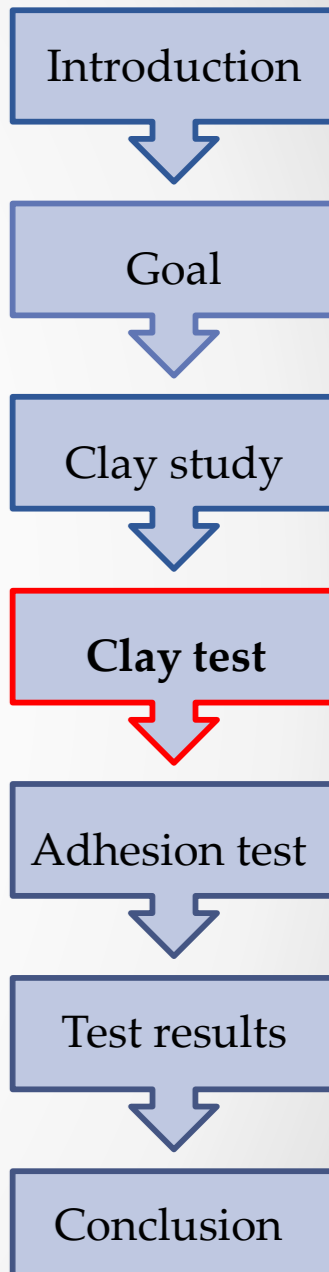
Tested natural field clays:

- Delaware River clay, Philadelphia, PA
- Grey Freeport clay, Freeport, TX
- Red Freeport clay, Freeport, TX

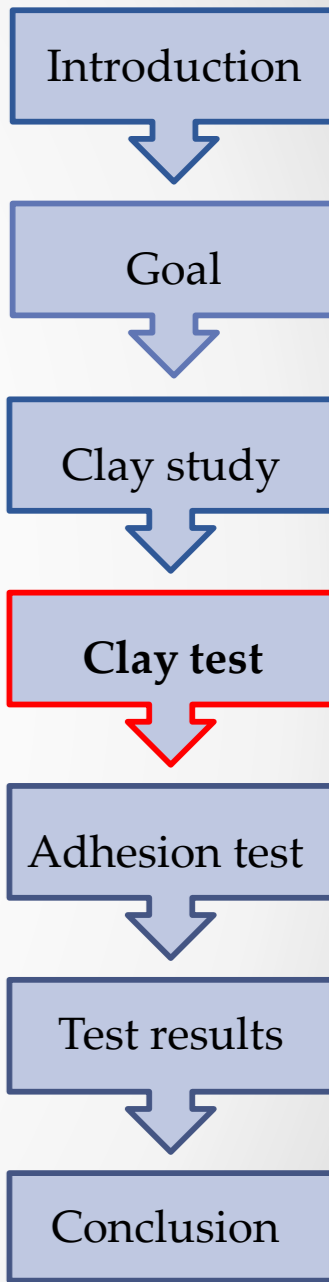


Tests:

- Atterberg limits
- Mineralogy
- Density
- UU-traxial test (cohesive strength)
- **Adhesion test (designed test set-up)**



NATURAL FIELD CLAYS

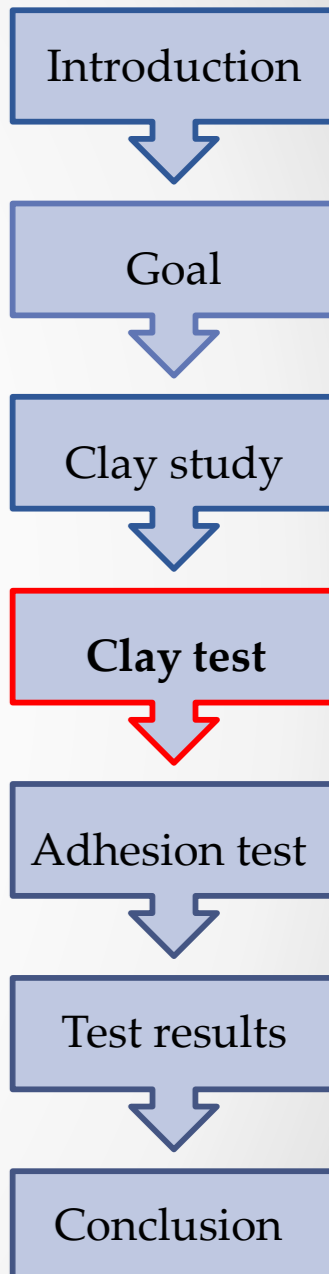


MINERALOGY

X-Ray diffraction

- Reflection of atomic and molecular structures to identify different types

Phase	Delaware River clay	Freeport Grey clay	Freeport Red clay
Quartz	52%	31%	19%
Mica/illite	20%	59%	60%
Kaolinite	27%	2%	9%



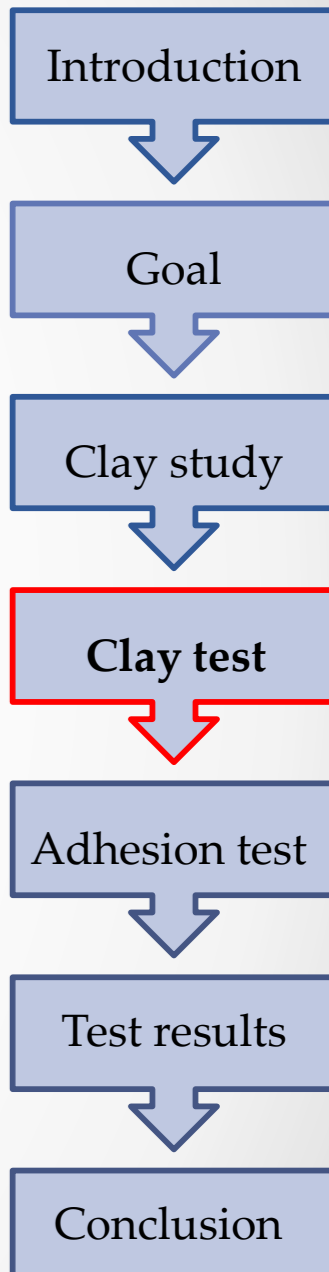
UU-TRAXIAL TEST

UU-traxial test

- Unconsolidated, undrained traxial test

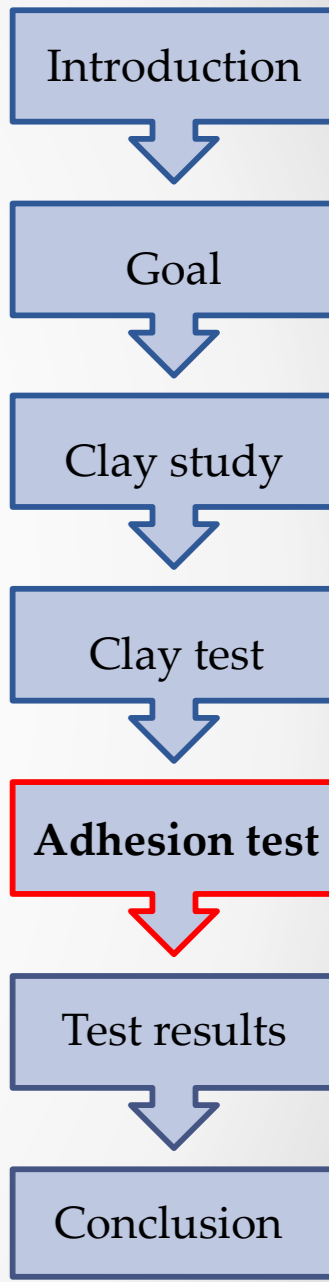
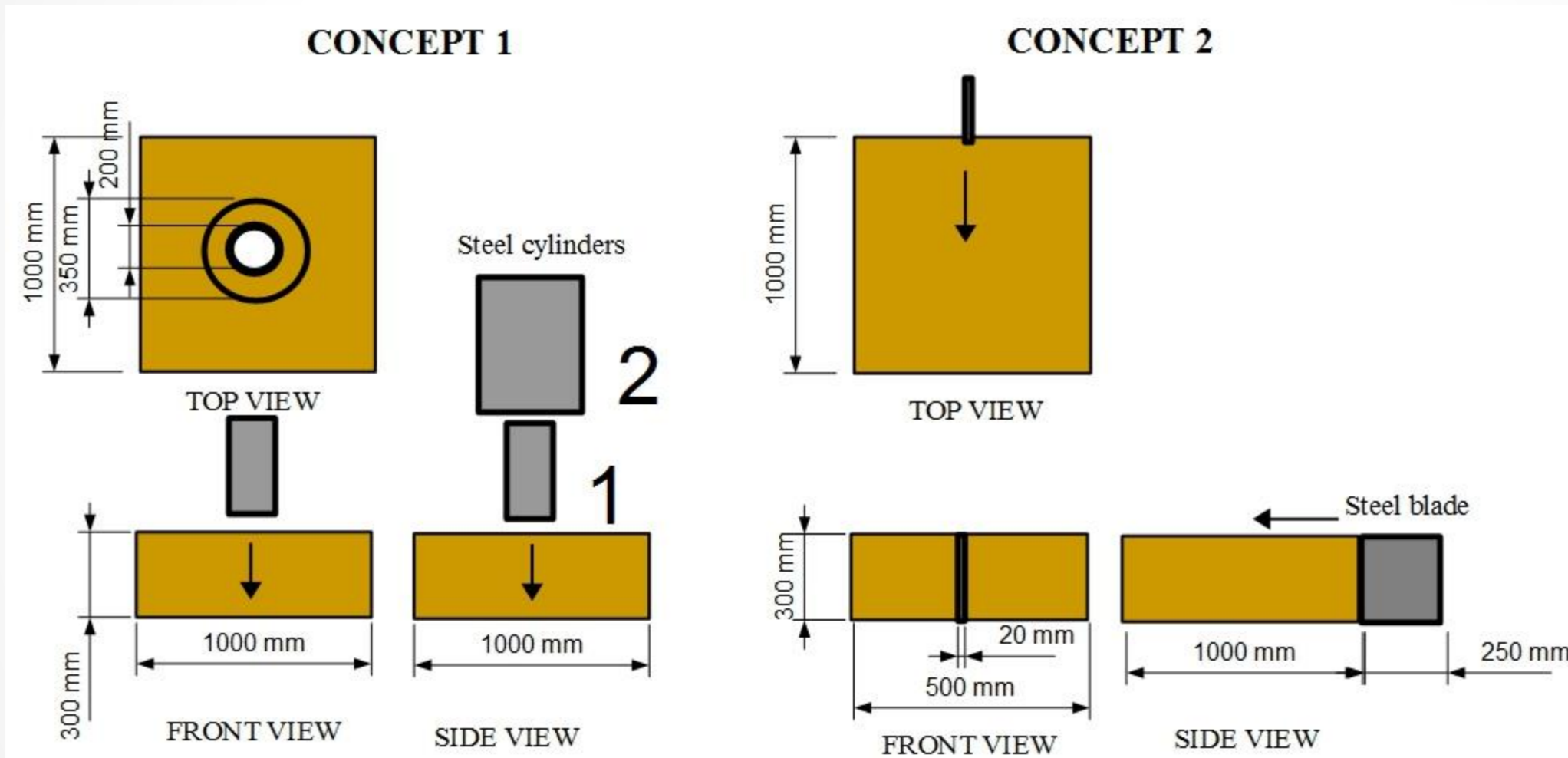


Clay	5%/hour [kPa] (standard)	100%/hour [kPa]	170%/hour [kPa]
Delaware River	12	11	10
Freeport Grey	22	17	14
Freeport Red	90	83	89

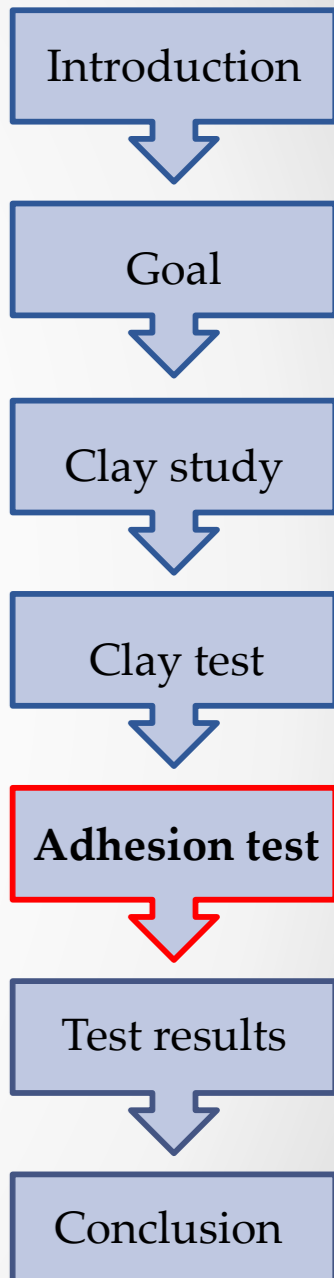
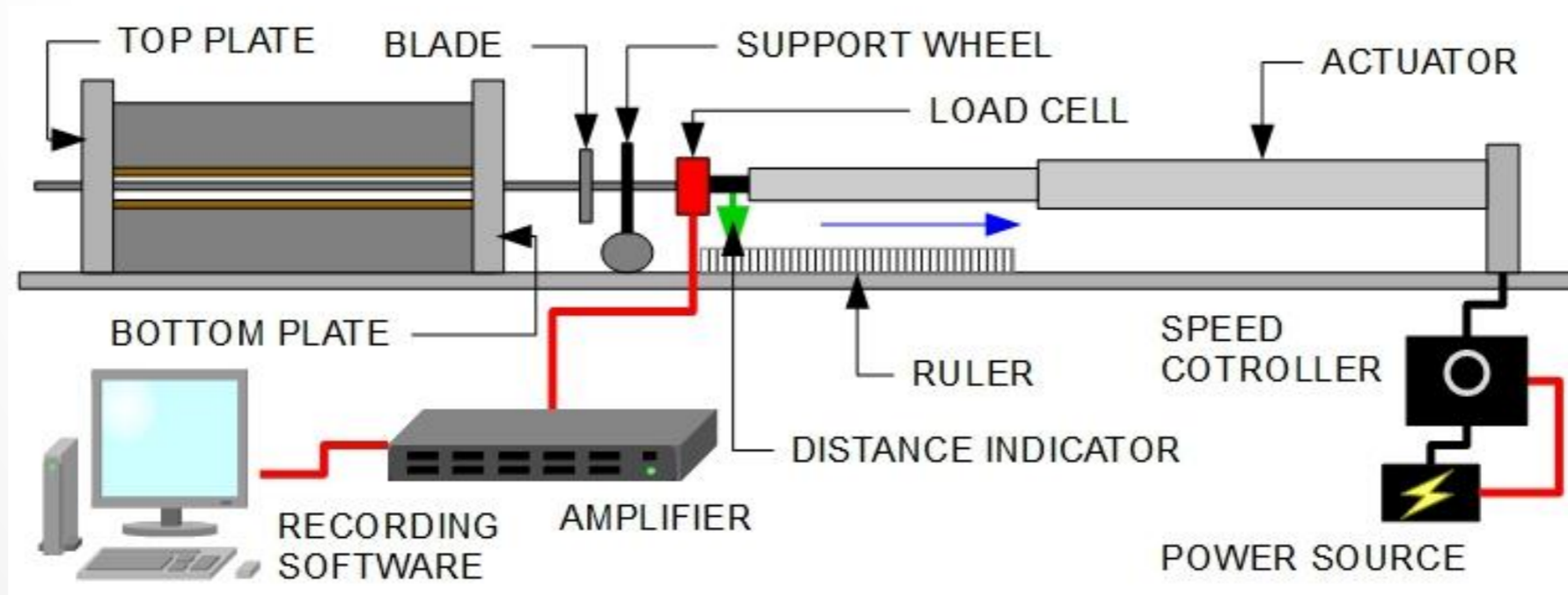


ADHESIVE TEST SET-UP

Concepts:



FINAL DESIGN

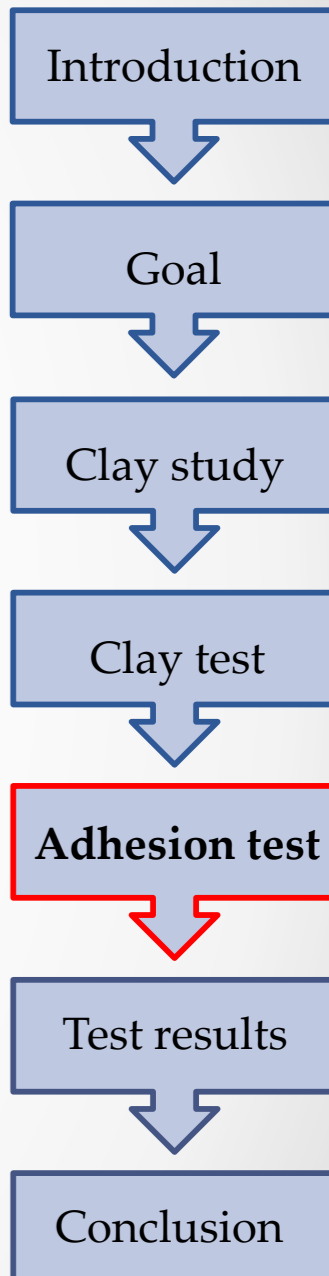


ADHESIVE TESTS

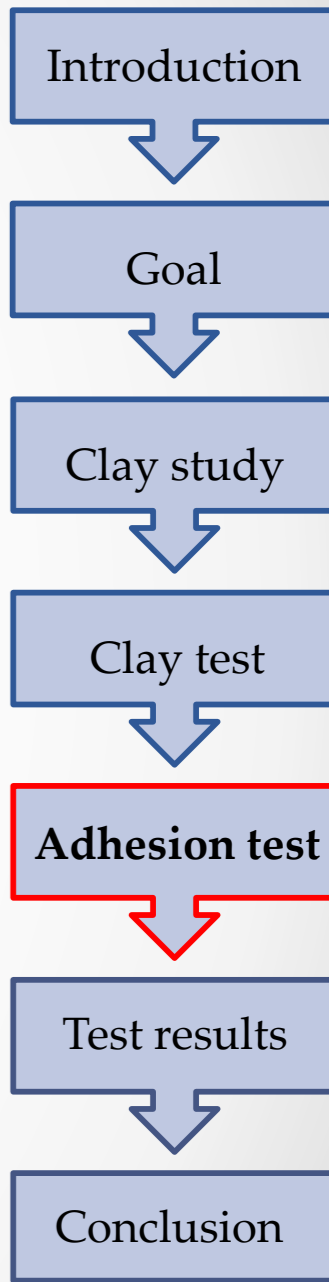
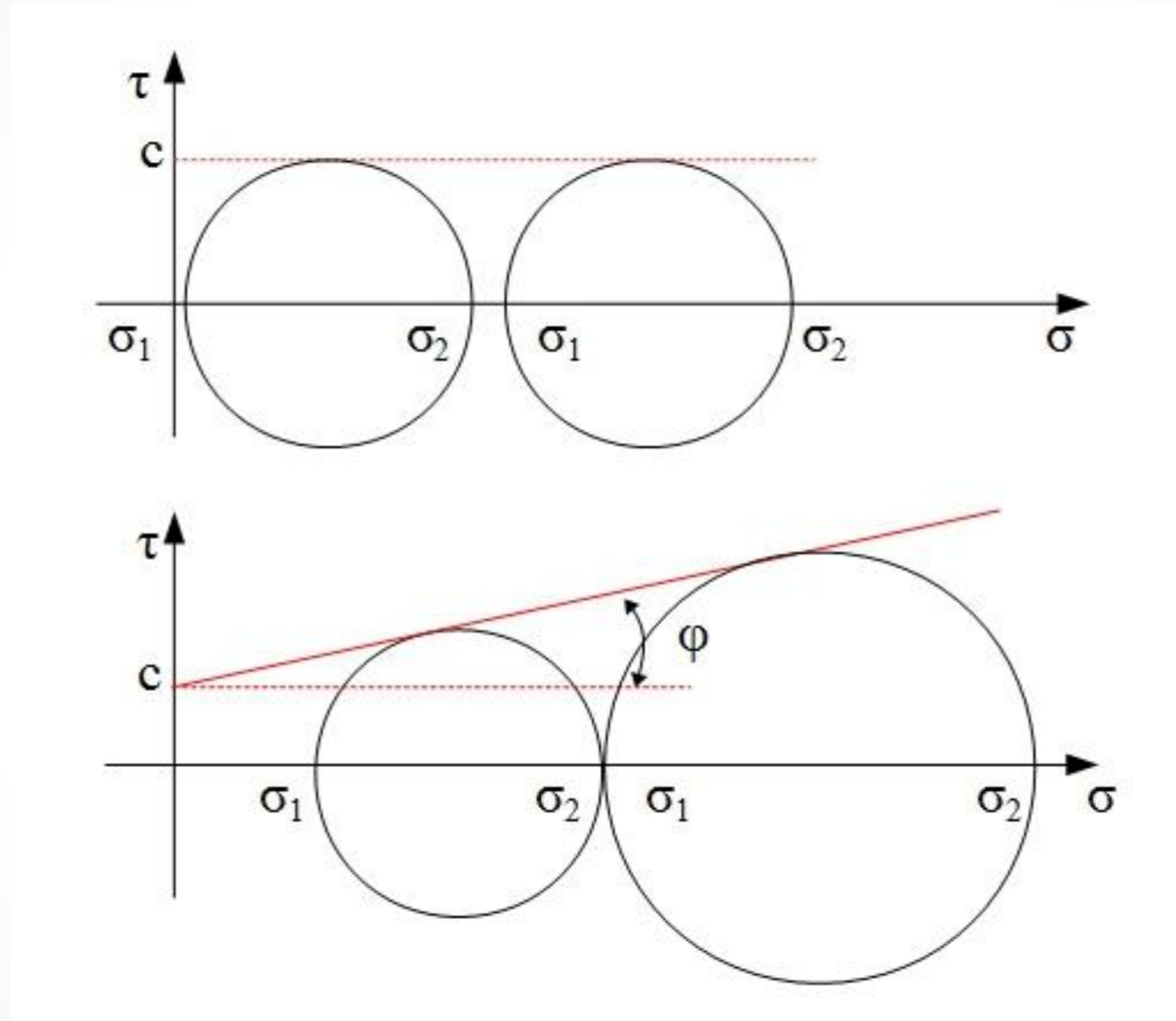
Adhesive tests:

- 3 natural field clays
- 3 vertical loads
 - Own weight
 - Own weight + weight 1
 - Own weight + weight 1 + weight 2
- 2 pulling speeds
 - 8 mm/s
 - 0.4 mm/s
- 3 repeats

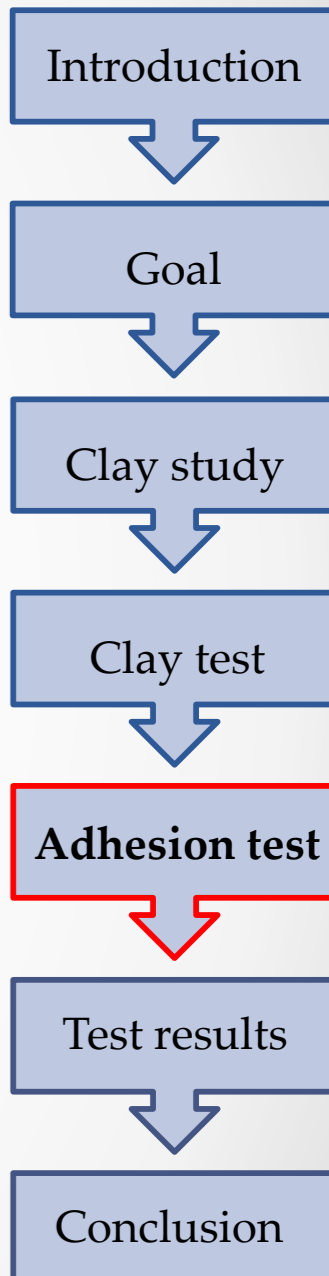
54 ADEHSIVE TESTS TOTAL



MOHR CIRCLE



ADHESIVE TESTS

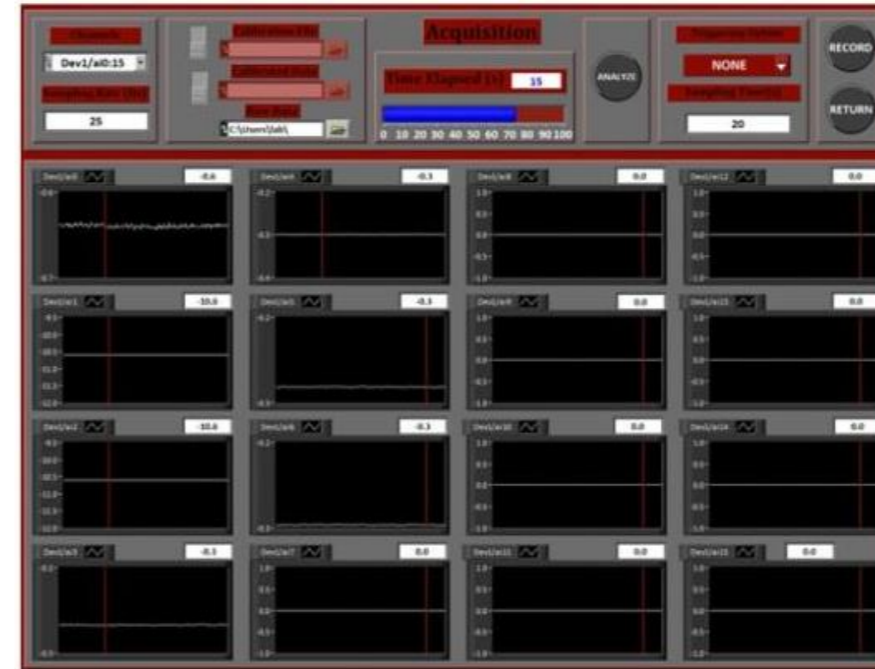


Top/bottom plate, speed controller, indicator, ruler

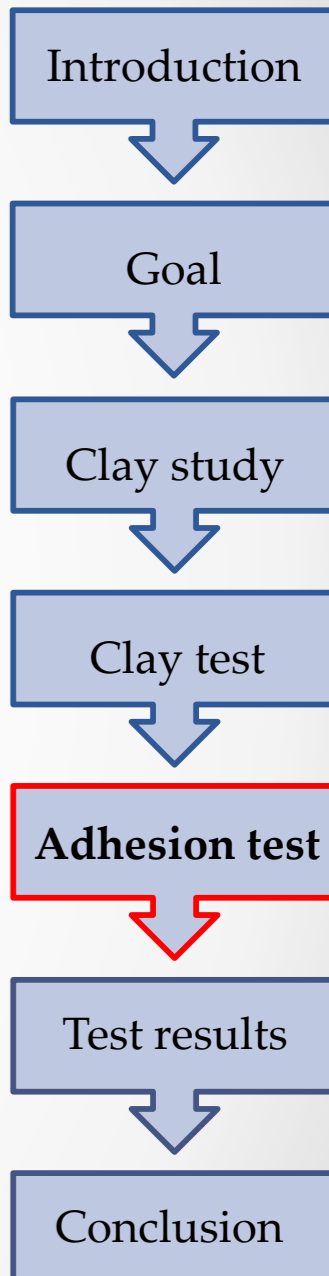
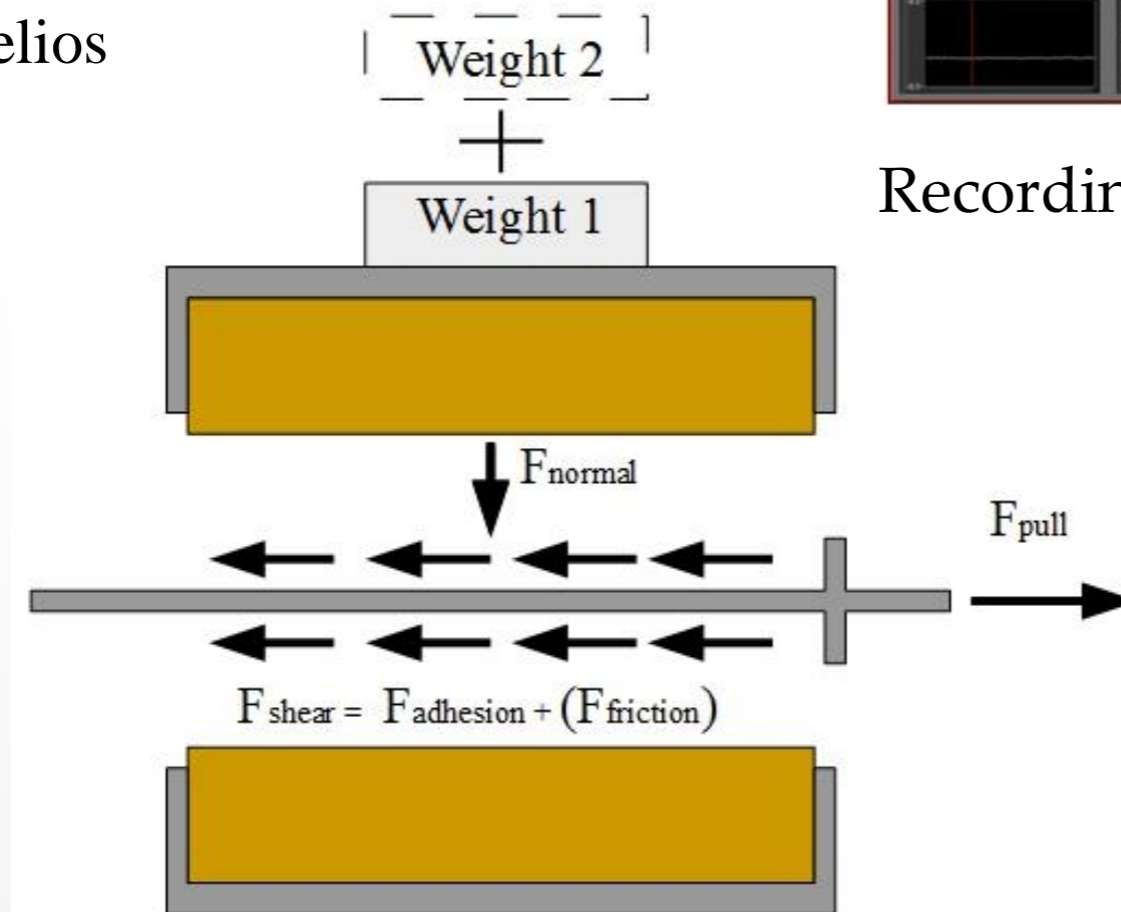
ADHESIVE TEST SET-UP

Recording equipment

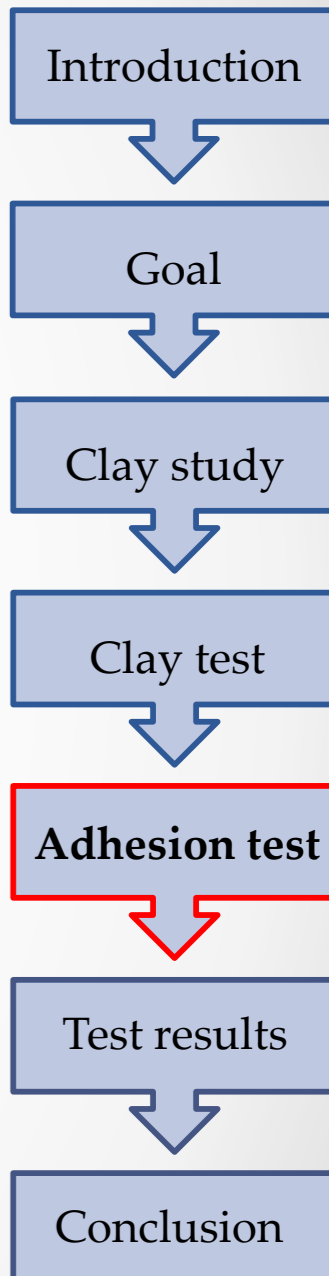
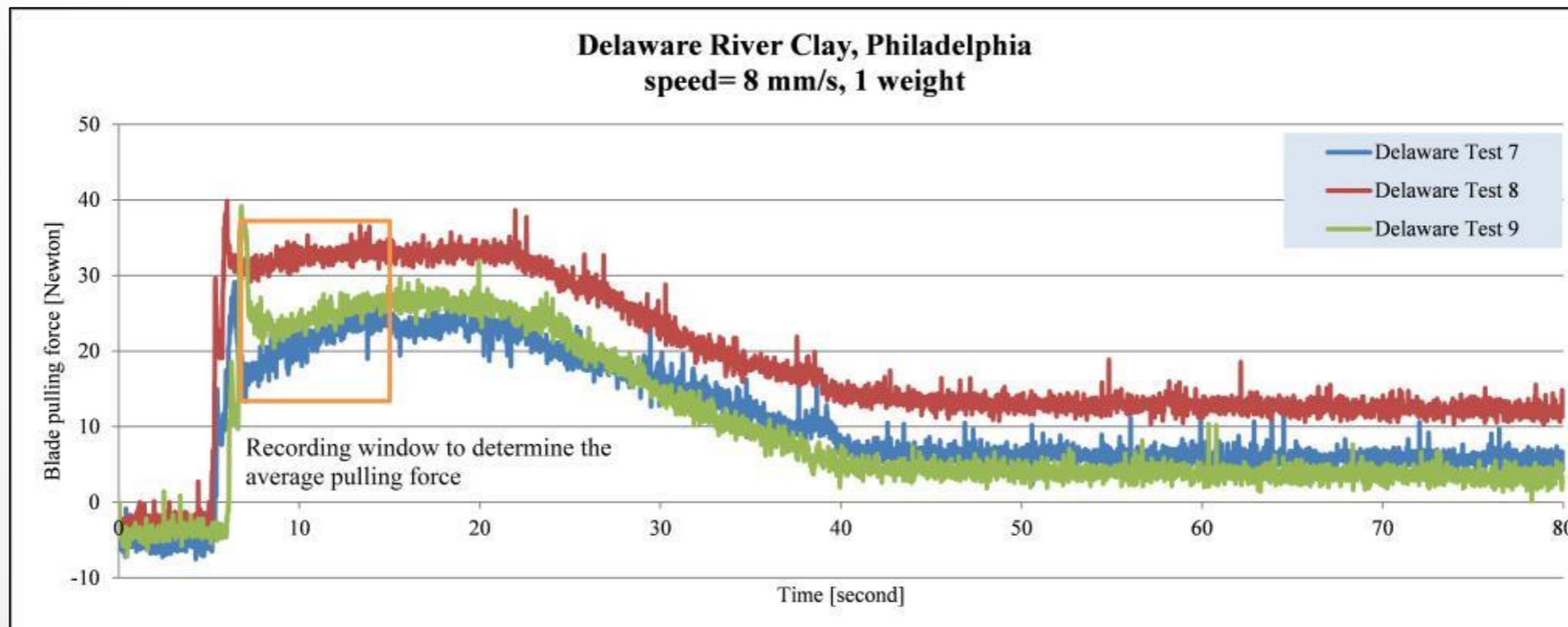
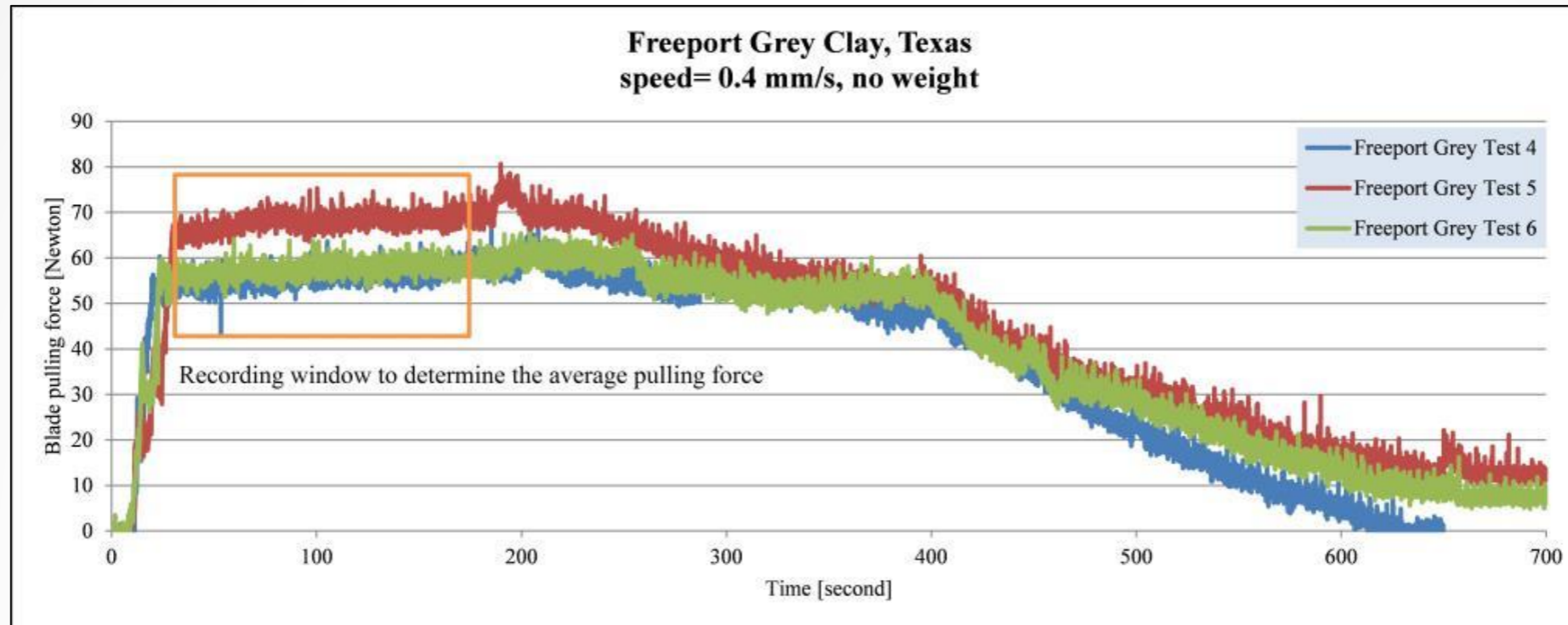
- Loading cell
 - Output voltage
- Amplifier
- Recording software
 - Helios



Recording display on computer



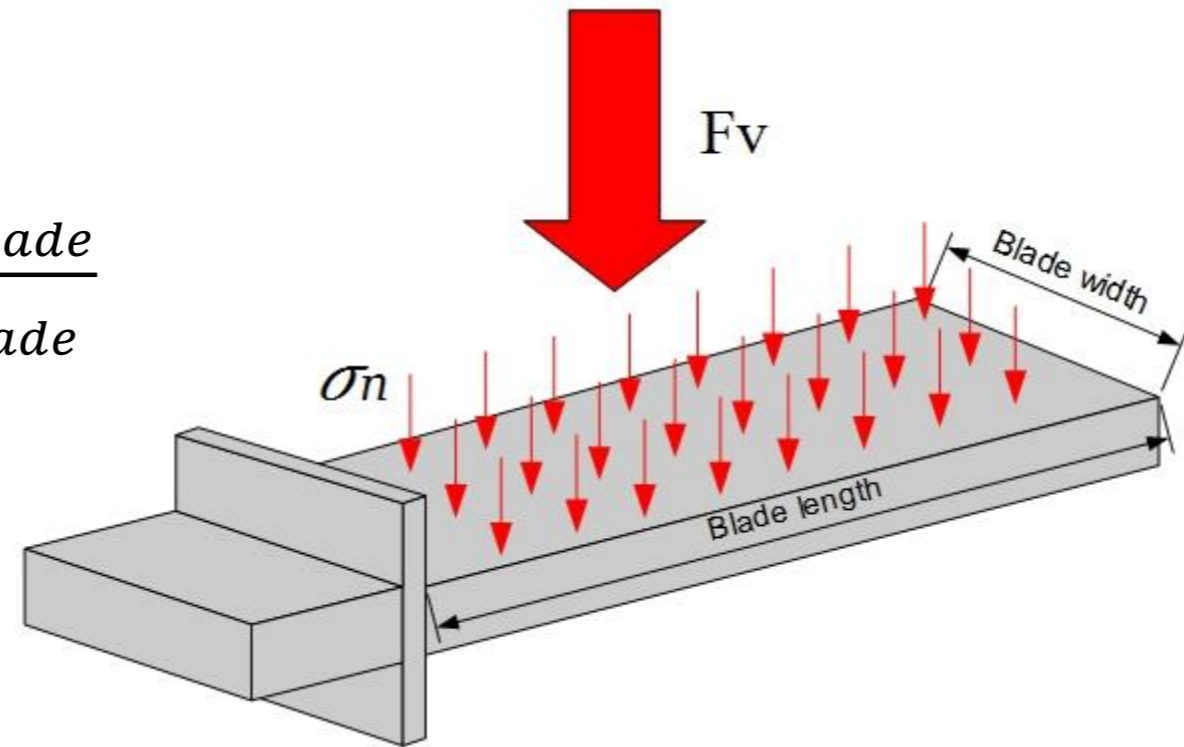
RECORDING OUTPUT



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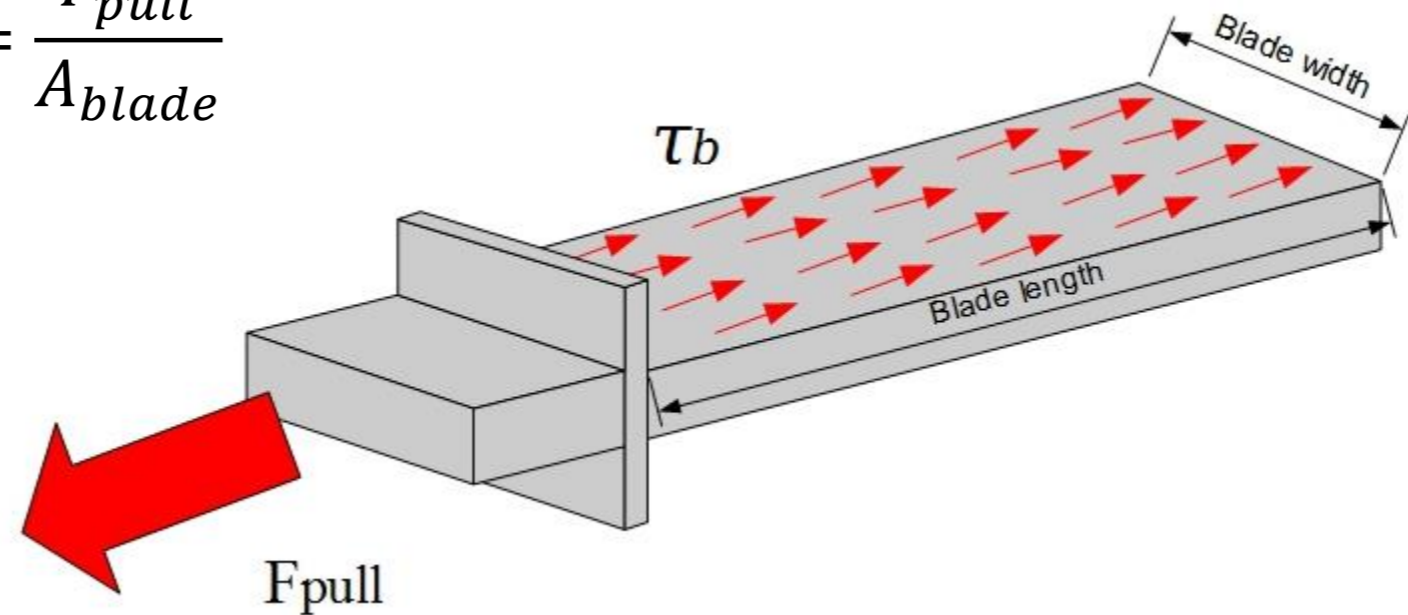
Normal stress:

$$\sigma_n = \frac{F_{v,blade}}{A_{blade}}$$



Shear stress:

$$\tau_b = \frac{F_{pull}}{A_{blade}}$$



Introduction

Goal

Clay study

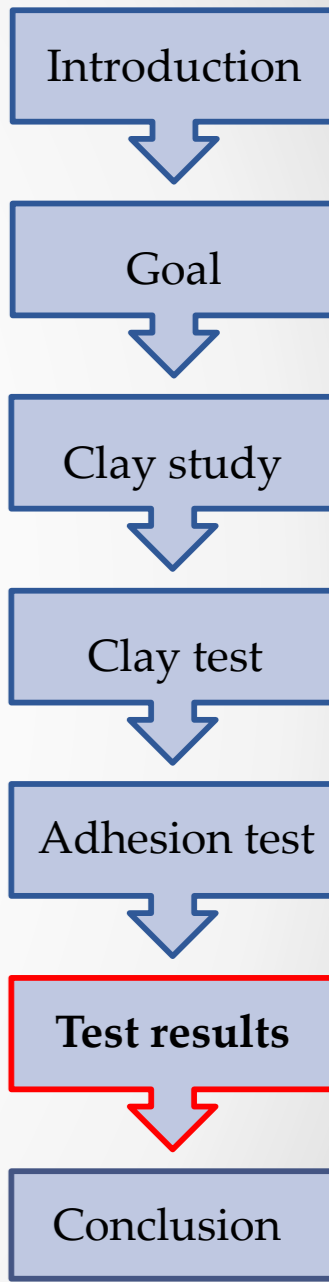
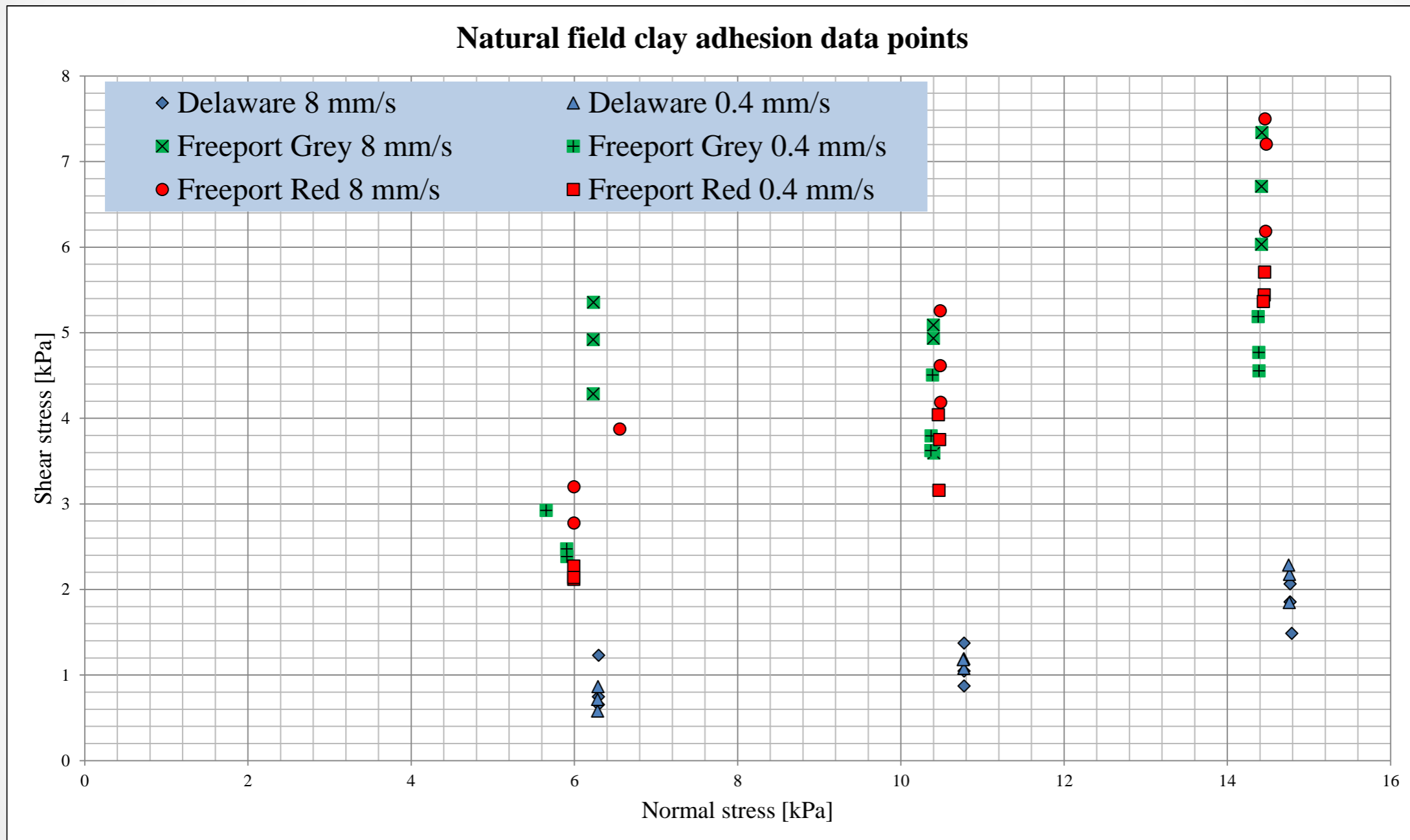
Clay test

Adhesion test

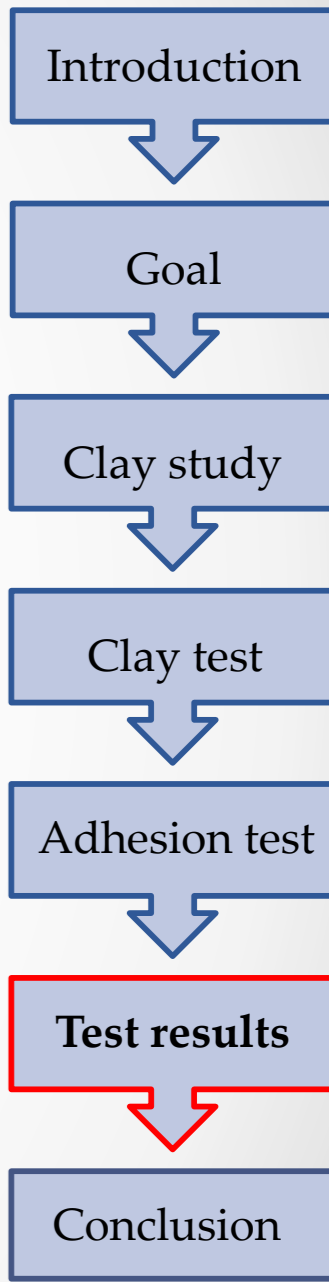
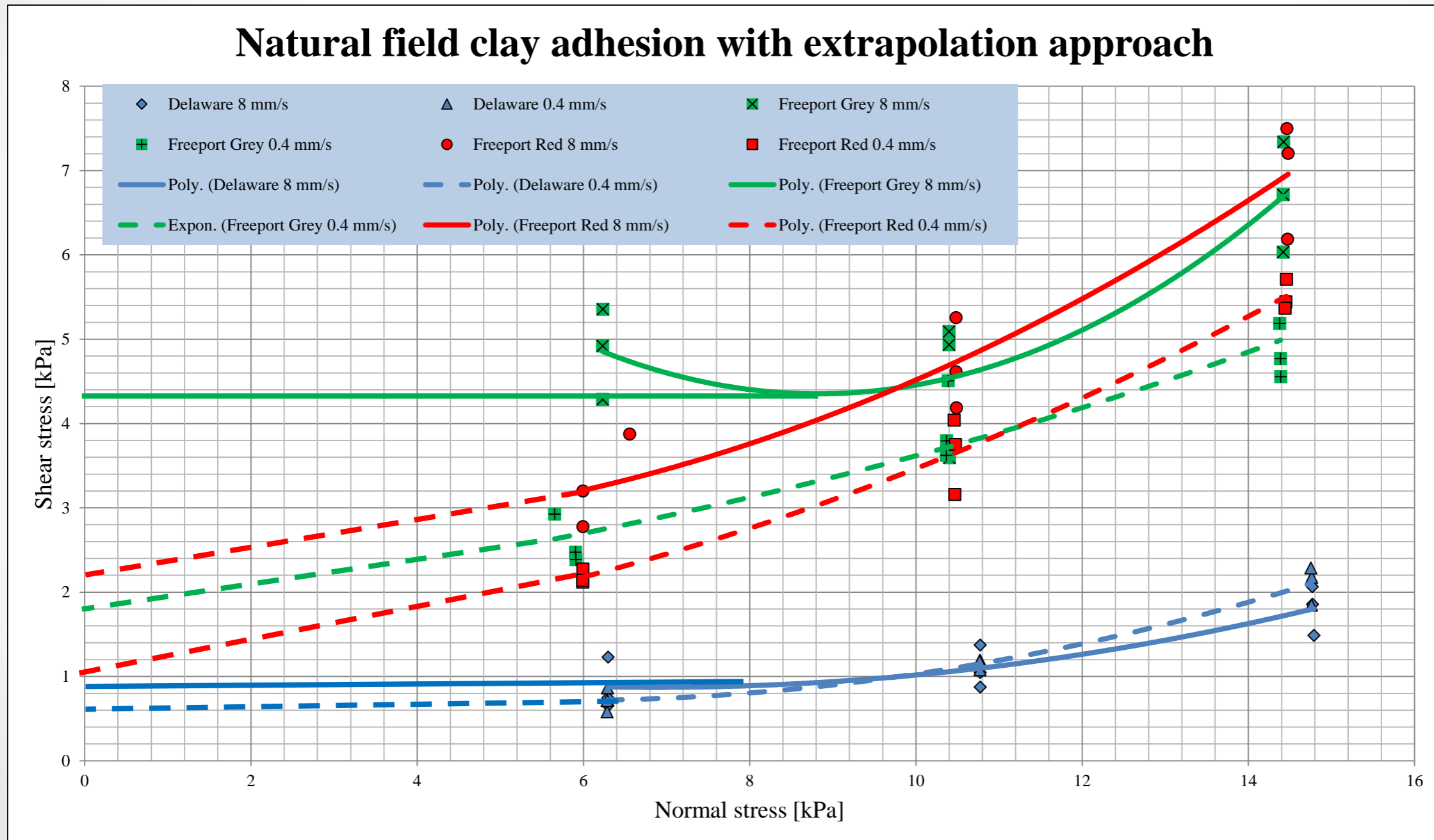
Test results

Conclusion

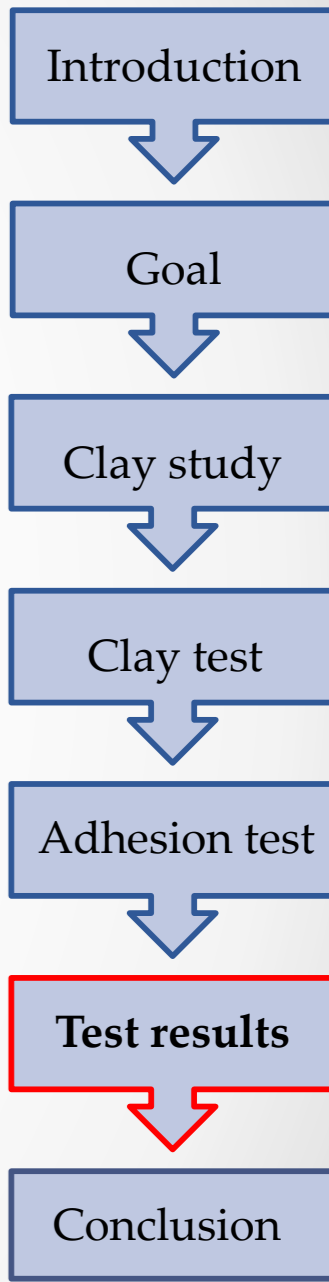
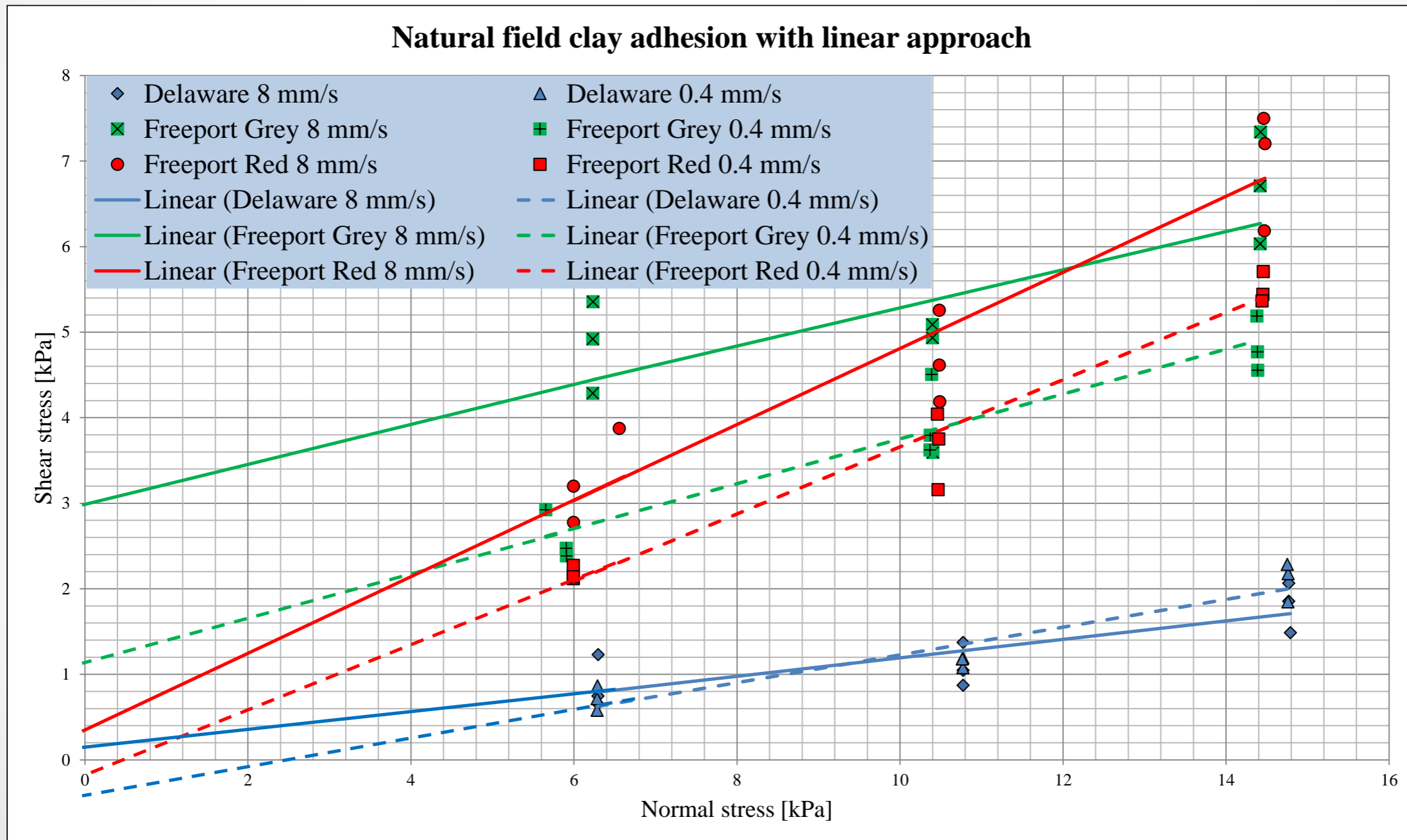
ADHESIVE DATA POINTS



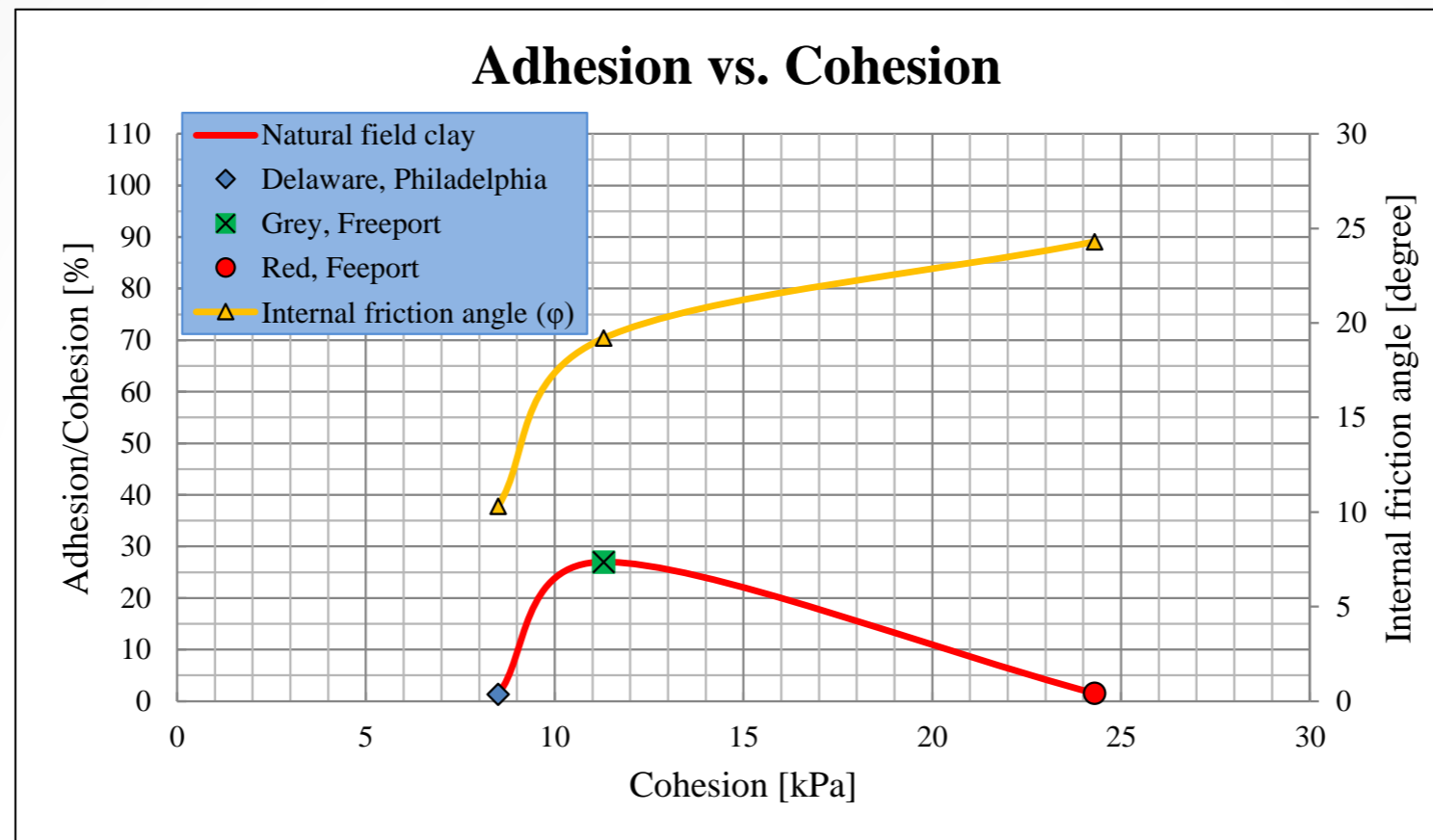
ADHESIVE EXTRAPOLATION APPROACH



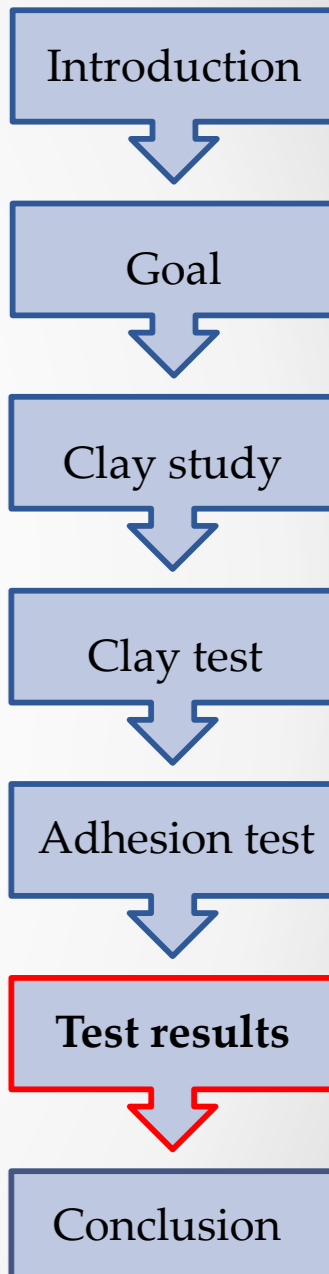
ADHESIVE LINEAR APPROACH



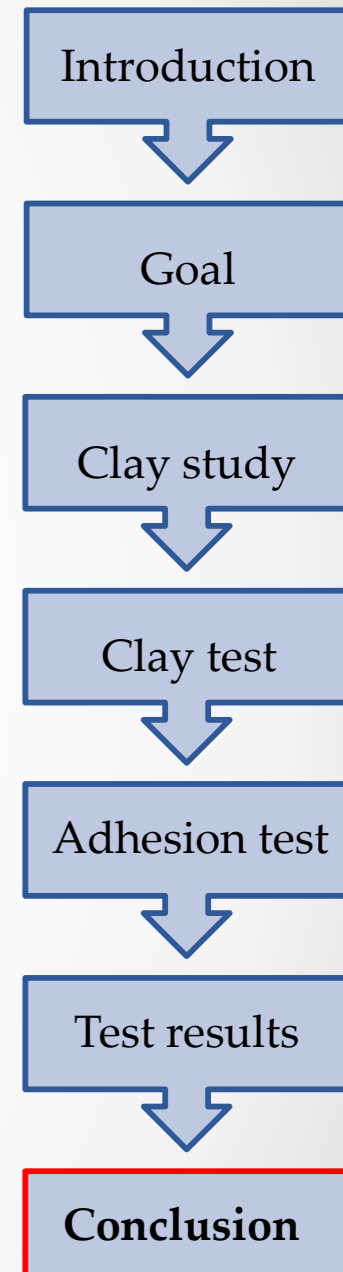
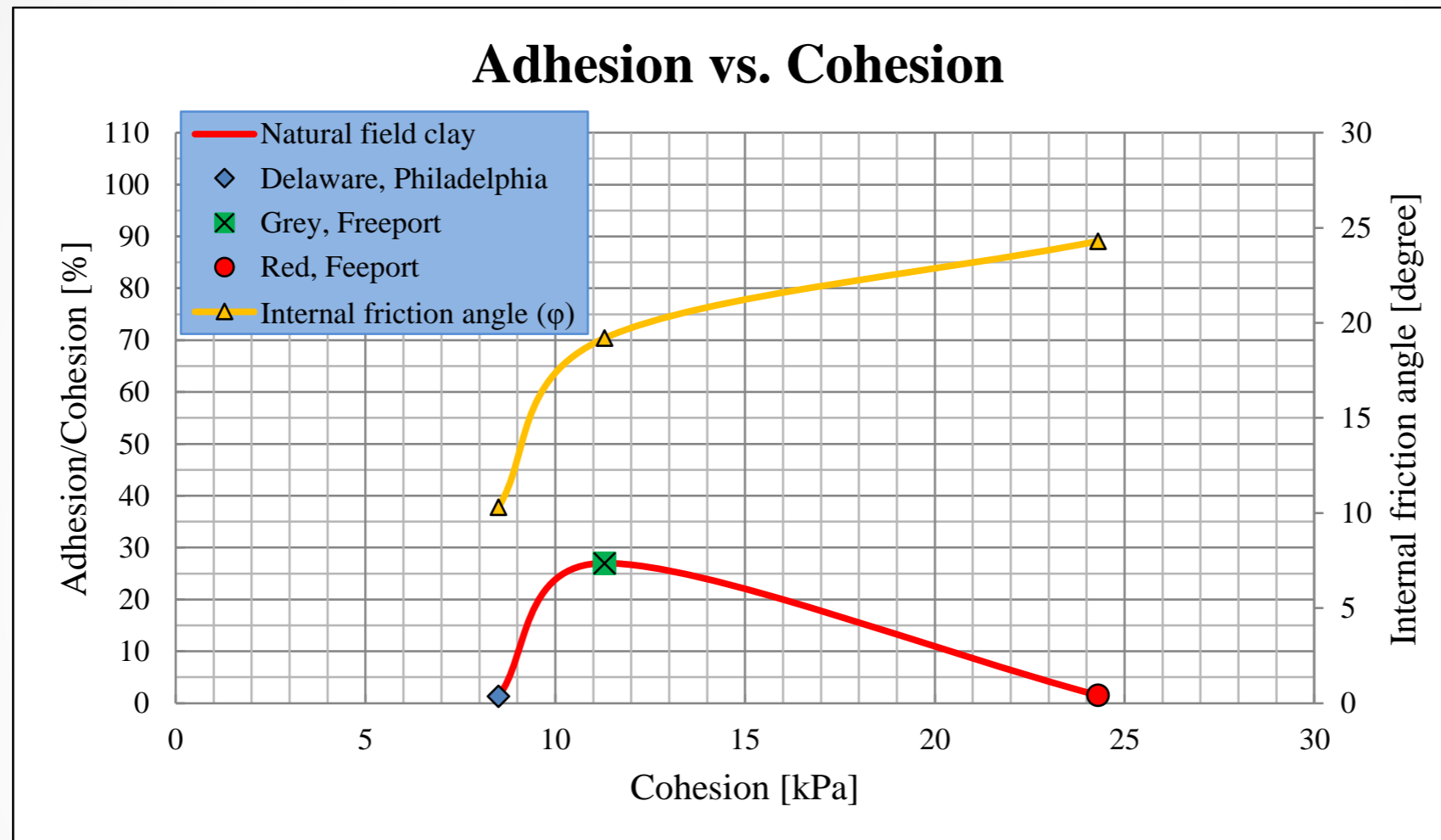
ADHESIVE DATA RESULTS



Clay	Cohesion [kPa]	Adhesion [kPa]	A/C [%]	Internal friction angle [degree]
Delaware 8	8.5	0.11	1.3	10.3
Delaware 0.4	9.4	0	0	10.4
Freeport G 8	11.3	3.05	27.0	19.2
Freeport G 0.4	18.3	1.13	6.2	16.3
Freeport R 8	24.3	0.36	1.5	24.3
Freeport R 0.4	43.1	0	0	43.1



ADHESIVE DATA RESULTS



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CONCLUSION CLAY STUDY

Natural field clay test

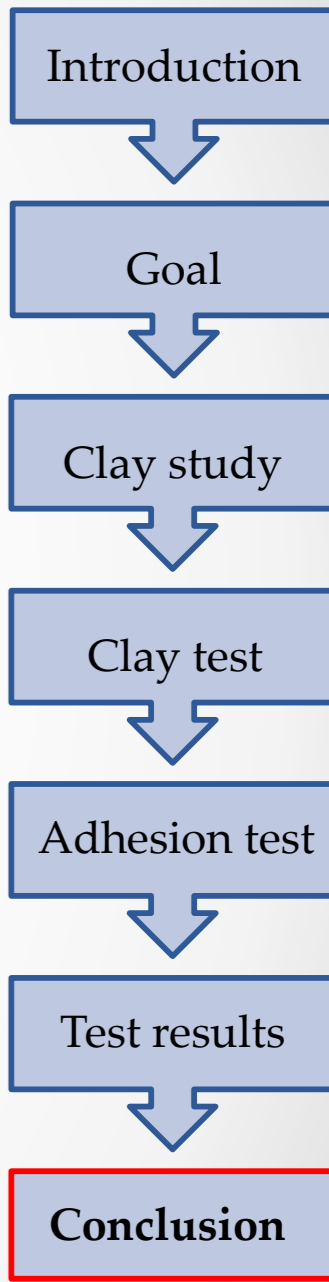
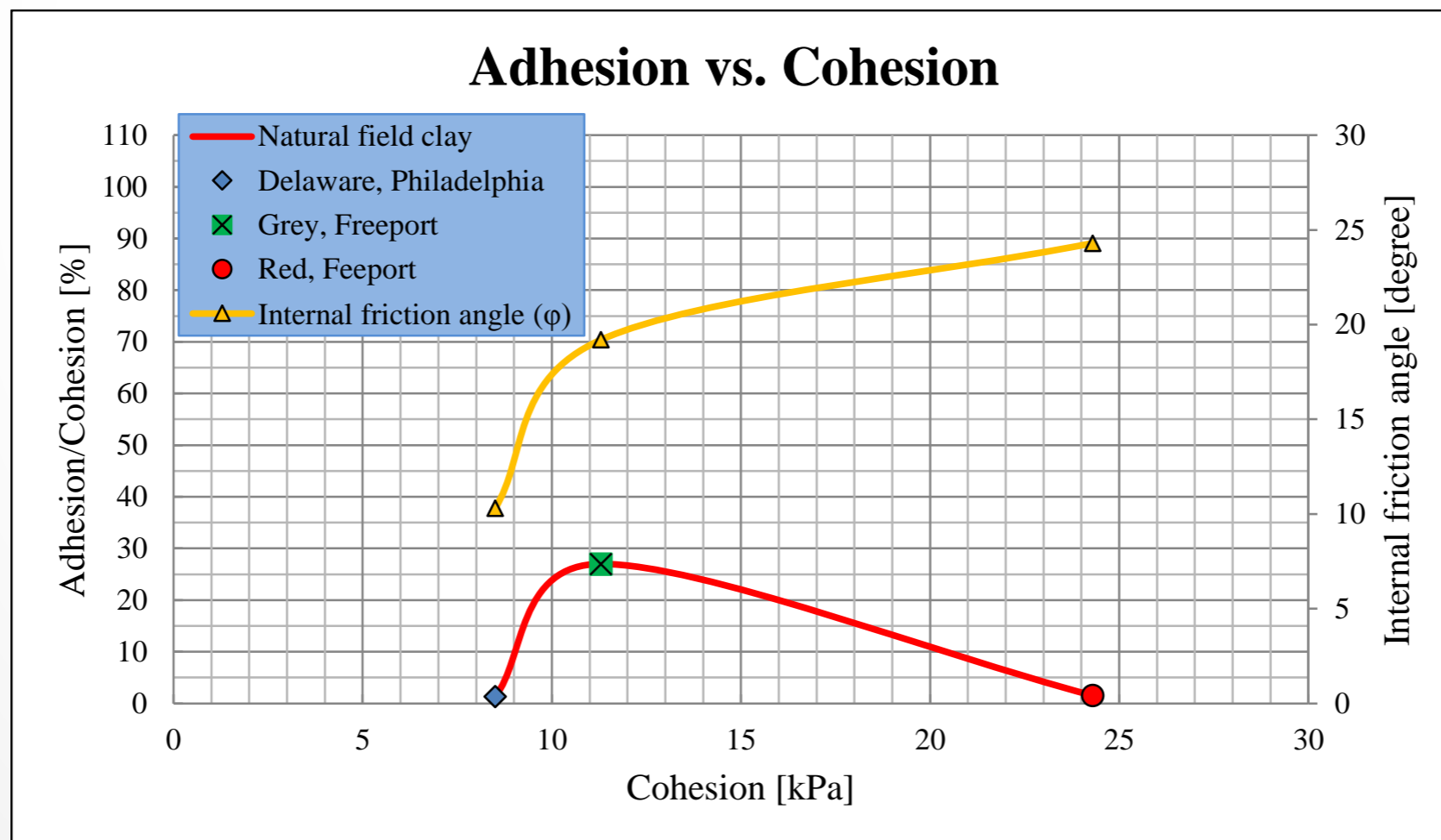
Relation cohesion vs. adhesion

- Increasing cohesion (c)
- Decrease adhesion (a)



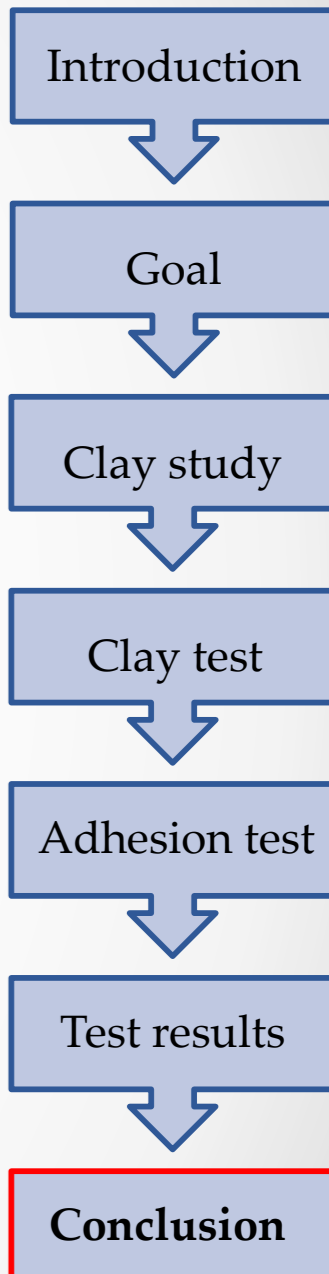
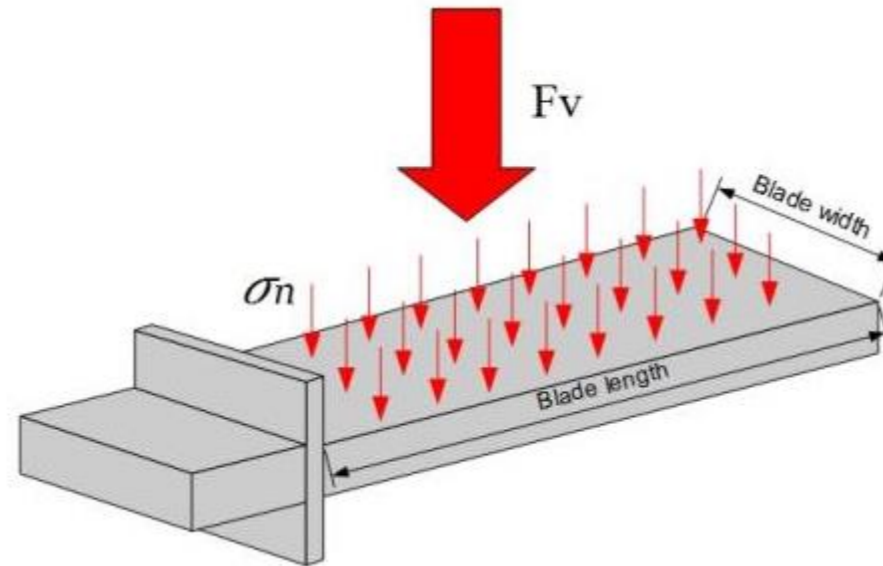
Bucket design
Production estimates
In-Field adaption

Additional to the relation is an increasing internal friction angle (ϕ)



RECOMENDATION

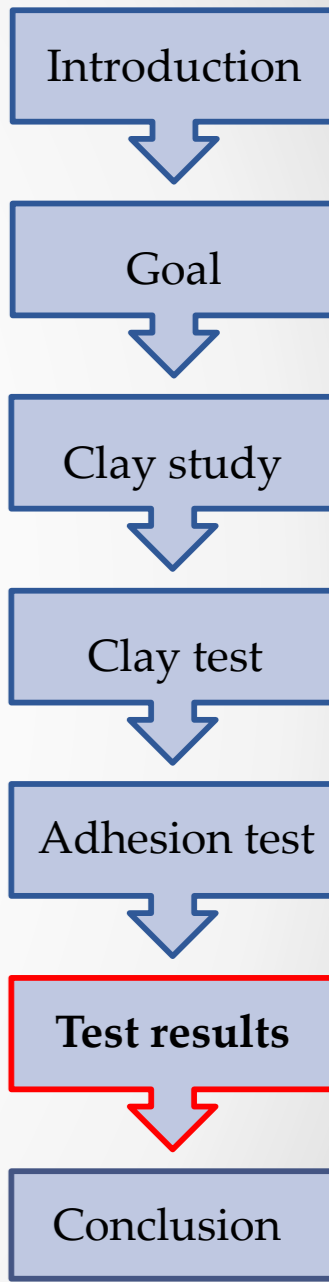
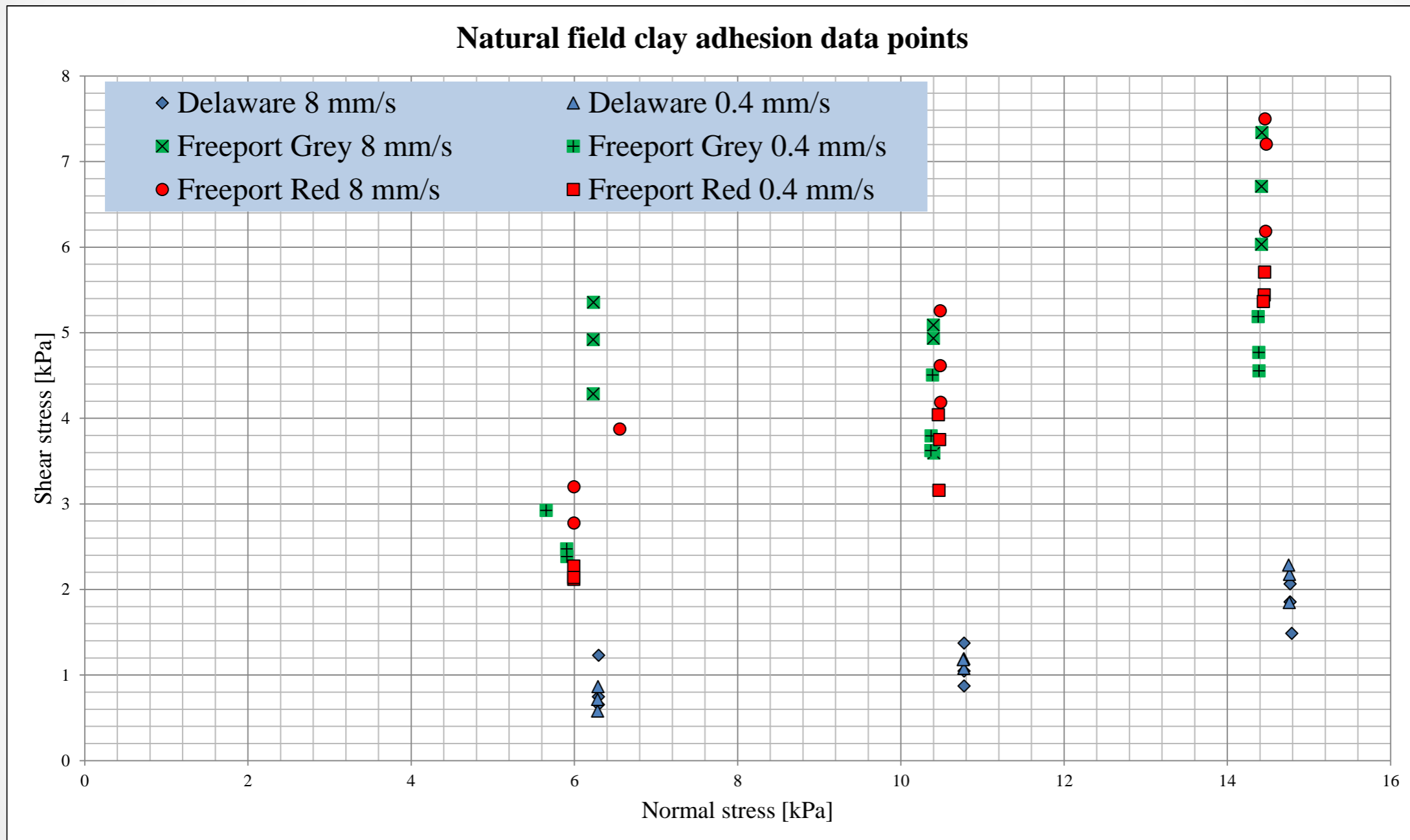
- **Increase normal stress on blade**
 - 200 kPa normal stress
 - Comparable with other studies
- **Increase blade length**
 - For a larger recording window
- **Test more natural field clays**
 - to verify design and use of adhesive test set-up
- **Test remolded natural field clay**
 - Examine the effect for adhesion measurements



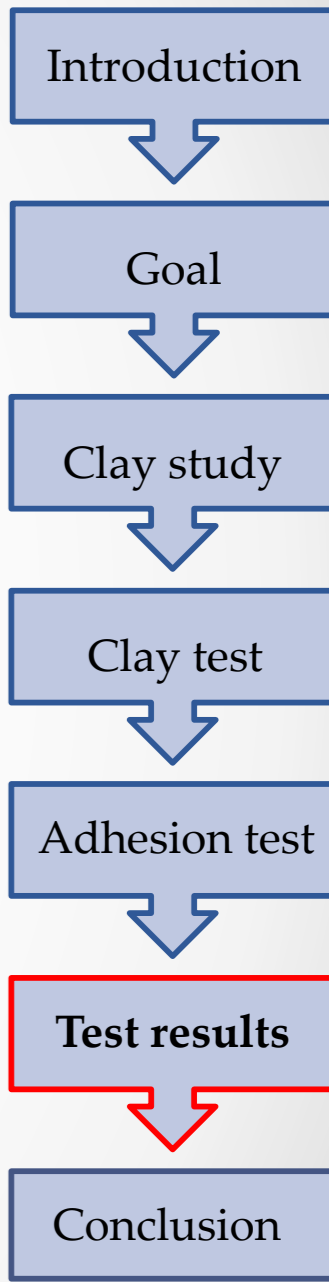
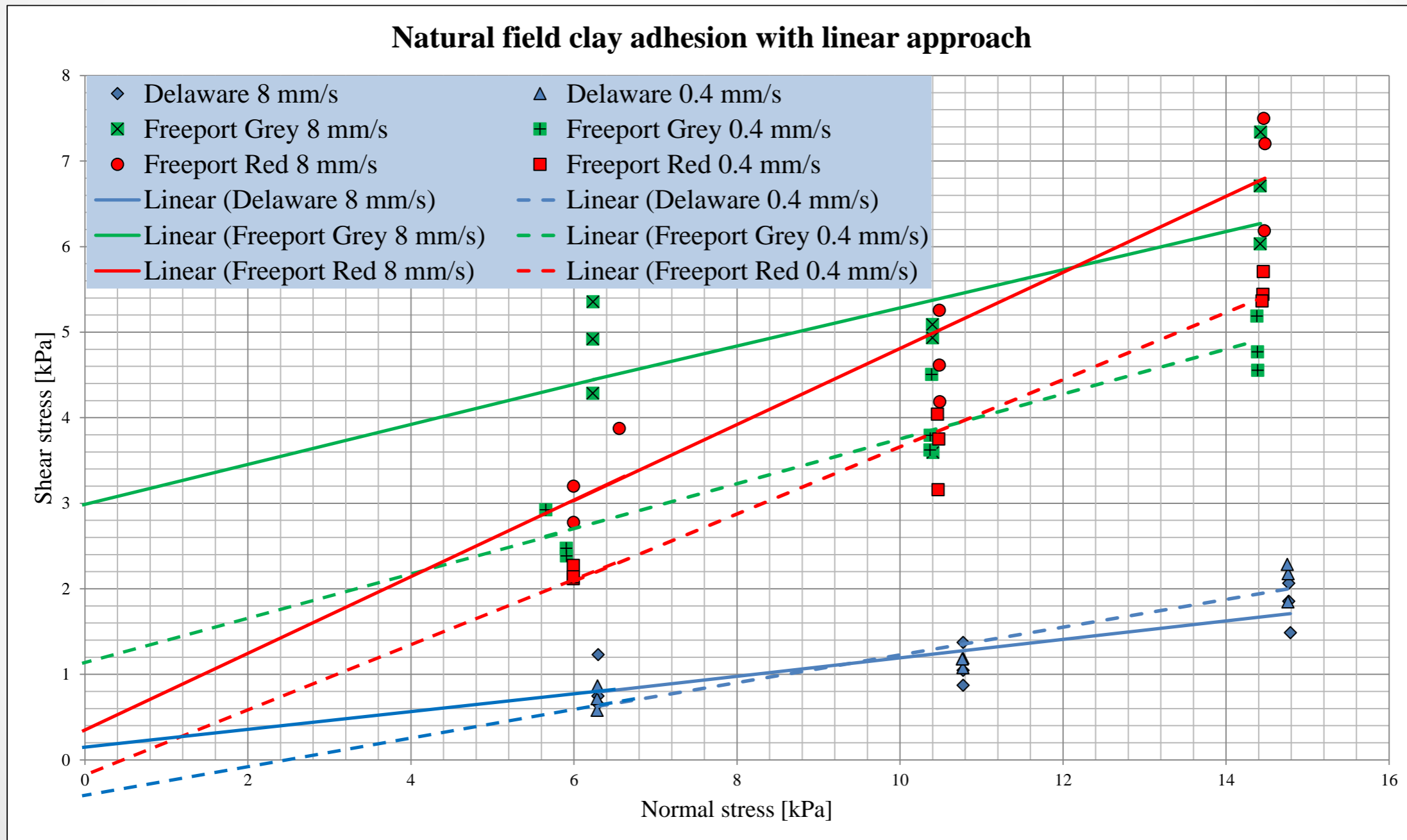
QUESTIONS?



ADHESIVE DATA POINTS



ADHESIVE LINEAR APPROACH



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