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Rheologische Eigenschaften von Instandsetzungsmörteln und Steinersatzmassen – Messungen mit dem Würpelgerät

–

Rheological Properties of Repair Mortars – Measurements with the Wuerpel-Device

P. Ramge, H.-C. Kühne

Outline

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and Testing

- Repair Mortars
- The Wuerpel-Device
- Exemplary Experiments
- Conclusions

Repair Mortars

Introduction

Repair Mortars:

a) Concrete repair:

- Sprayed application
- Manual application
- Demands on mechanical properties are the ruling parameters

b) Natural stone repair in cultural heritage:

- Manual application
- Artistic execution
- Demands on aesthetical and historico-cultural aspects are dominant

Even though quite different in many aspects, the technology behind the scenes is basically the same

→ for both application fields similar rheological properties are needed

Repair Mortars

Introduction

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Repair Mortars

Rheological Requirements

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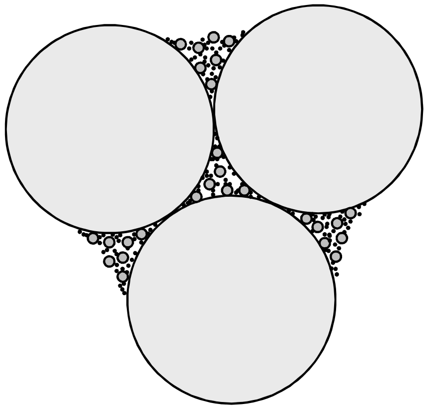
requirements:

1. low viscosity ⇨ pumping, manual application, smoothening
2. high (static) yield stress ⇨ no draining from vertical surfaces

⇨ „creamy “ consistency ⇨ a surplus of fines is needed

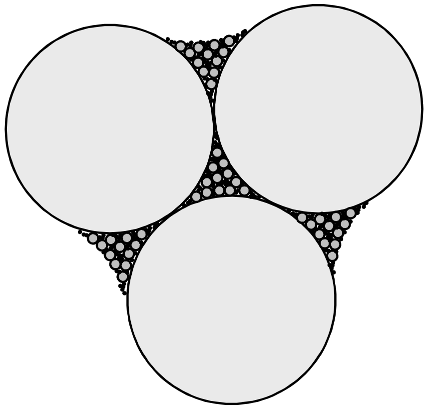
coarse particles dominant:

- to many voids, to much water needed
- no proper coherence without additional stabilizer



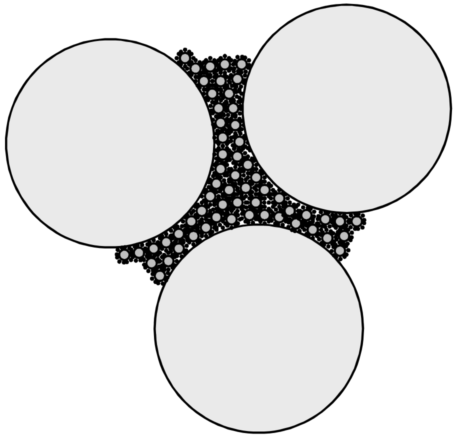
coarse and fine particles co dominant:

- lowest possible voids content, lowest water demand
- but very high viscosity



fine particles dominant:

- a bit more water needed
- low viscosity possible despite high solid content
- good coherence



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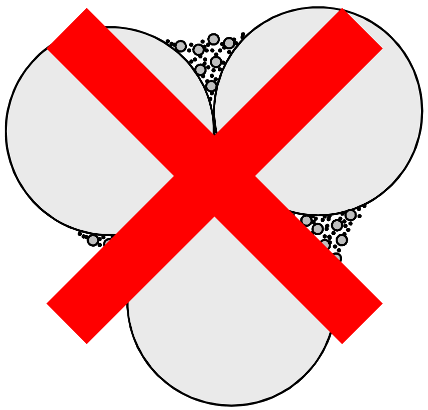

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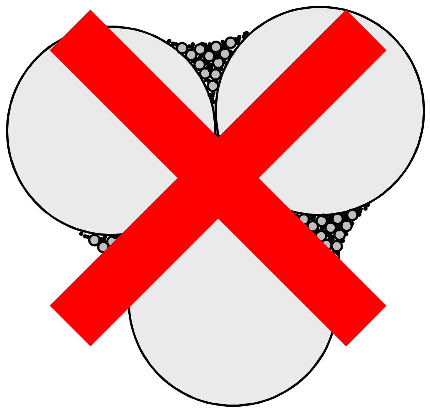

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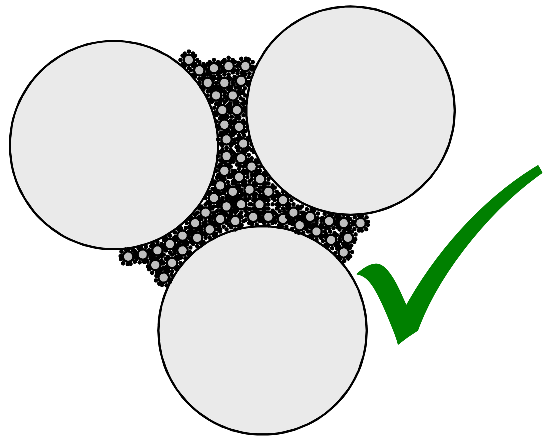
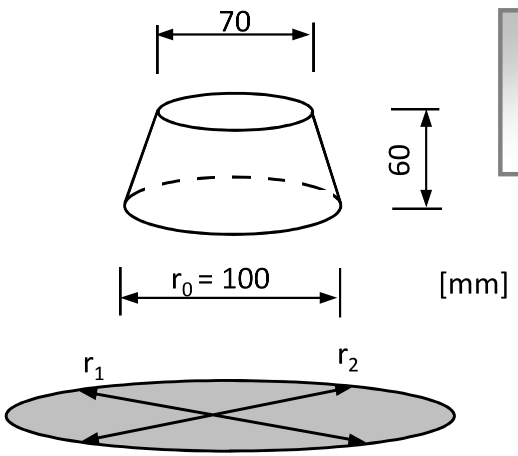


Repair Mortars

Rheological Requirements

Evaluation criterion „consistency“:

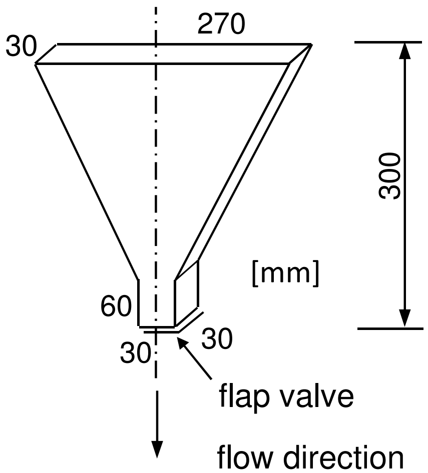


Flow diameter (Haegermann):

Good, but not sufficient

Rotational viscometer:

No satisfactory results, mortar does not flow back

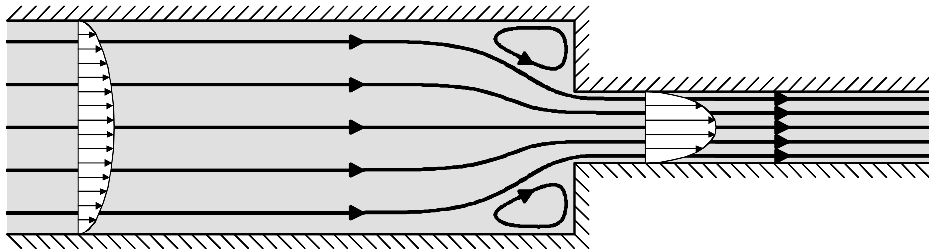


V-Funel:

inappropriate, because the mortar is not flowable

Actually wanted:

Pumping device similar to a capillary viscometer



Repair Mortars

Rheological Requirements

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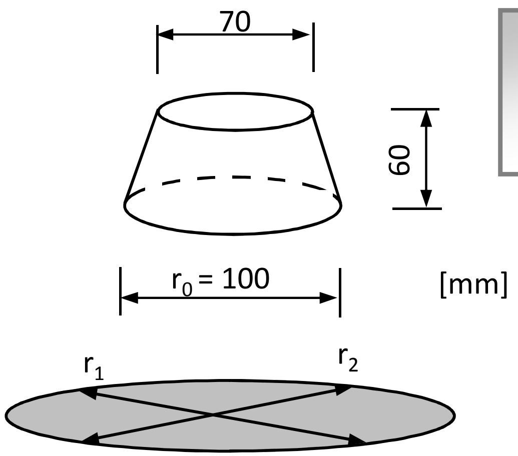

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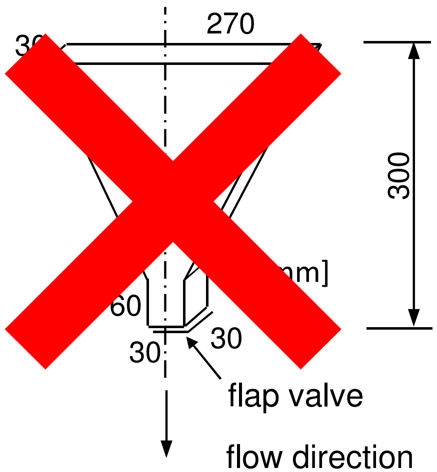

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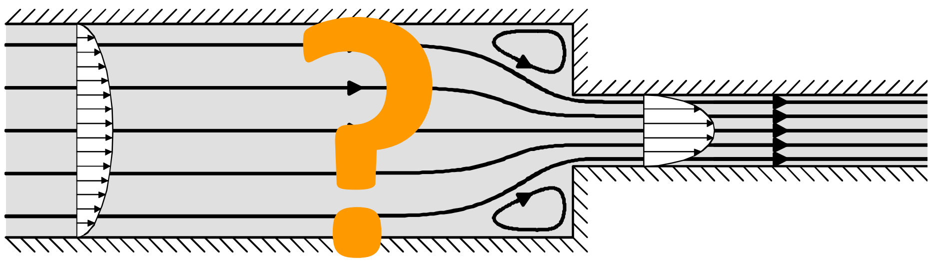

The Wuerpel-Device

- Named after Charles E. Wuerpel.
- Wuerpel worked with the device in the 1950s (first published 1952: C.E. Wuerpel, Masonry Cement in Proc. 3rd int. Symp. Chemistry of Cement).
- He called it "deformed cube method".
- His device was inspired by the "Plasticomèter" published by Berthier.
- Wuerpel modified the dimensions (reduced height of the mould) and the load application (load applied to one side only, the opposite edge fixed).

"Berthier-Plasticomèter" (1950)

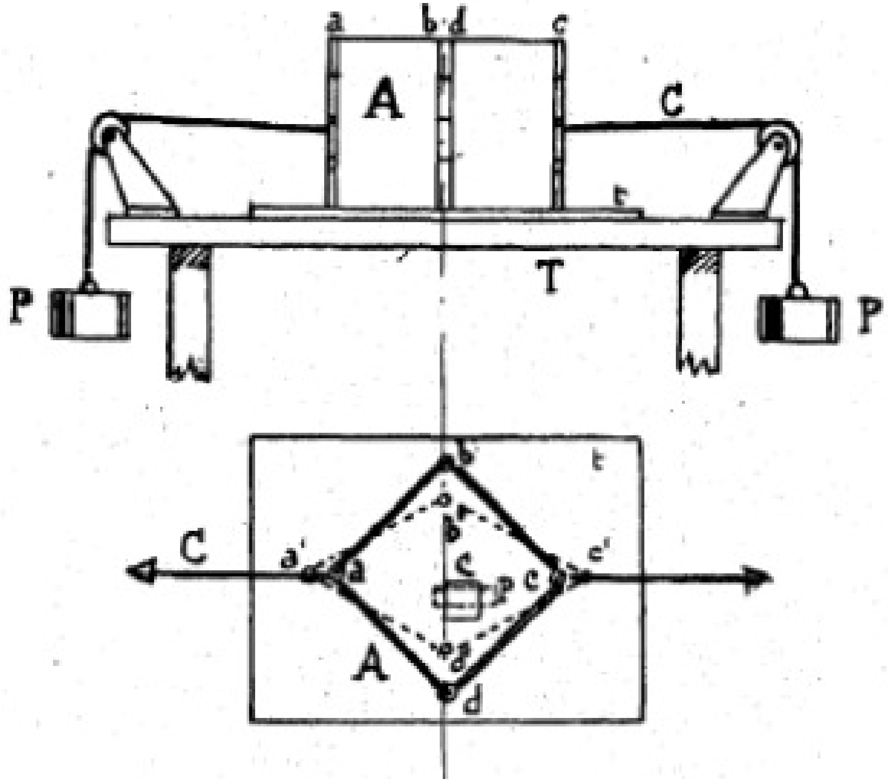

Image source: Berthier 1950

The Wuerpel-Device

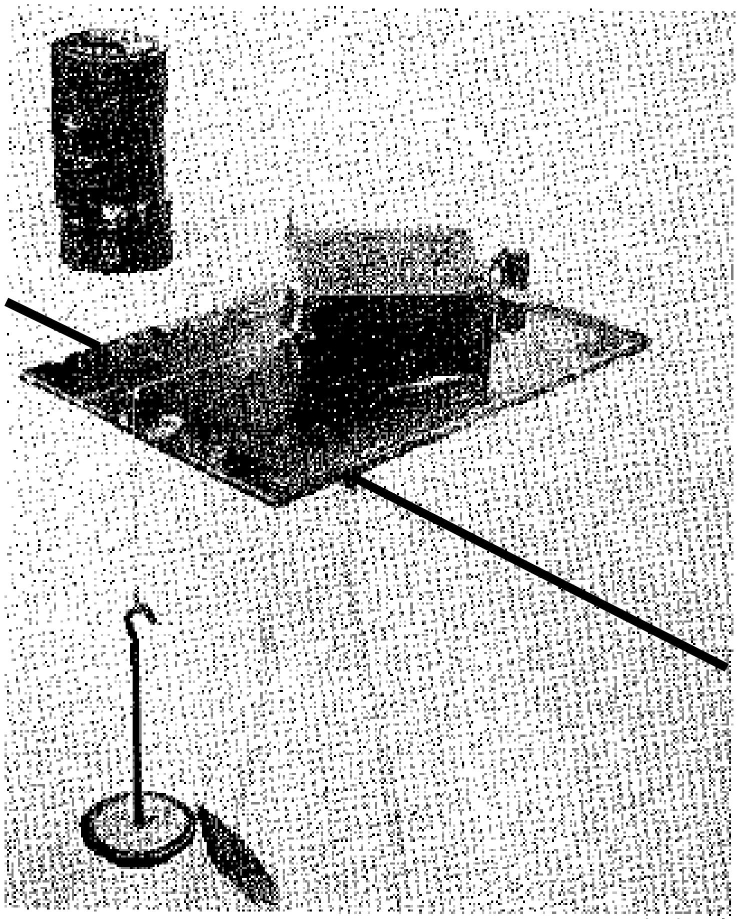

Figure 1 : Undeformed cube.

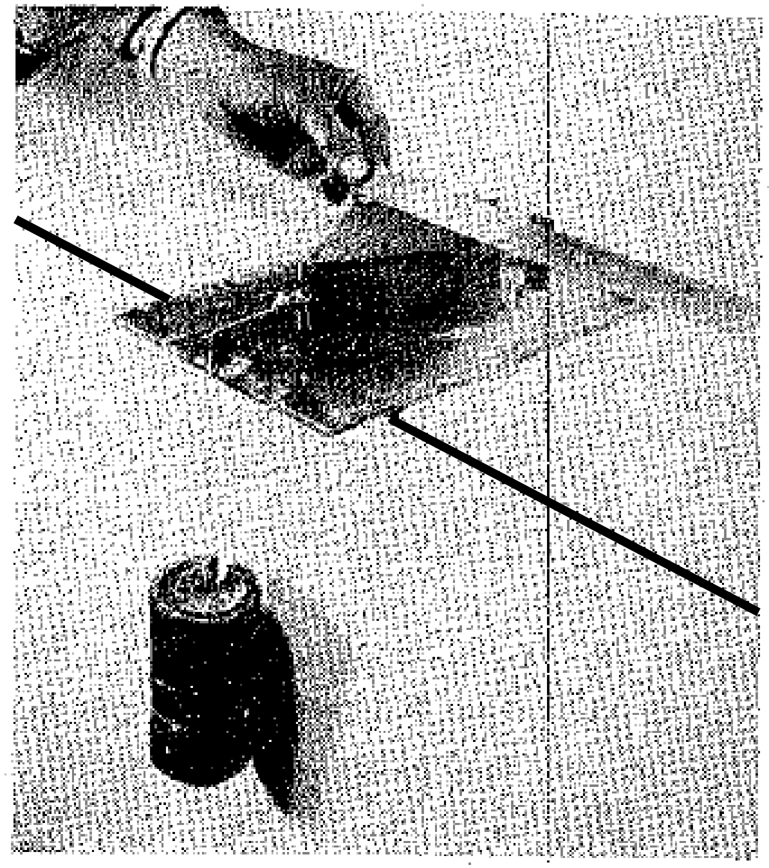

Figure 2 : Cube deformed.

Image source: C.E. Wuerpel 1952

The Wuerpel-Device

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Standardized versions

Developed in America in the 1950s:
load controlled device

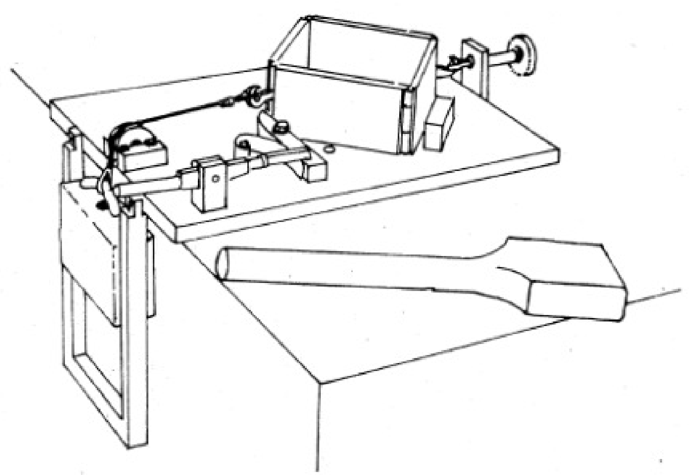

Image source: Ludwig & Schwiete 1962

Modified in Germany in the 1960s:
displacement controlled device

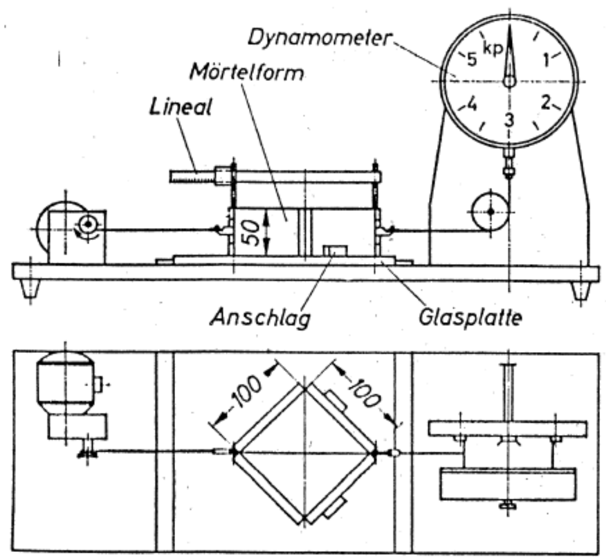

Image source: Ohnemüller 1967

Maximum displacement is measured

load-displacement-curve is recorded

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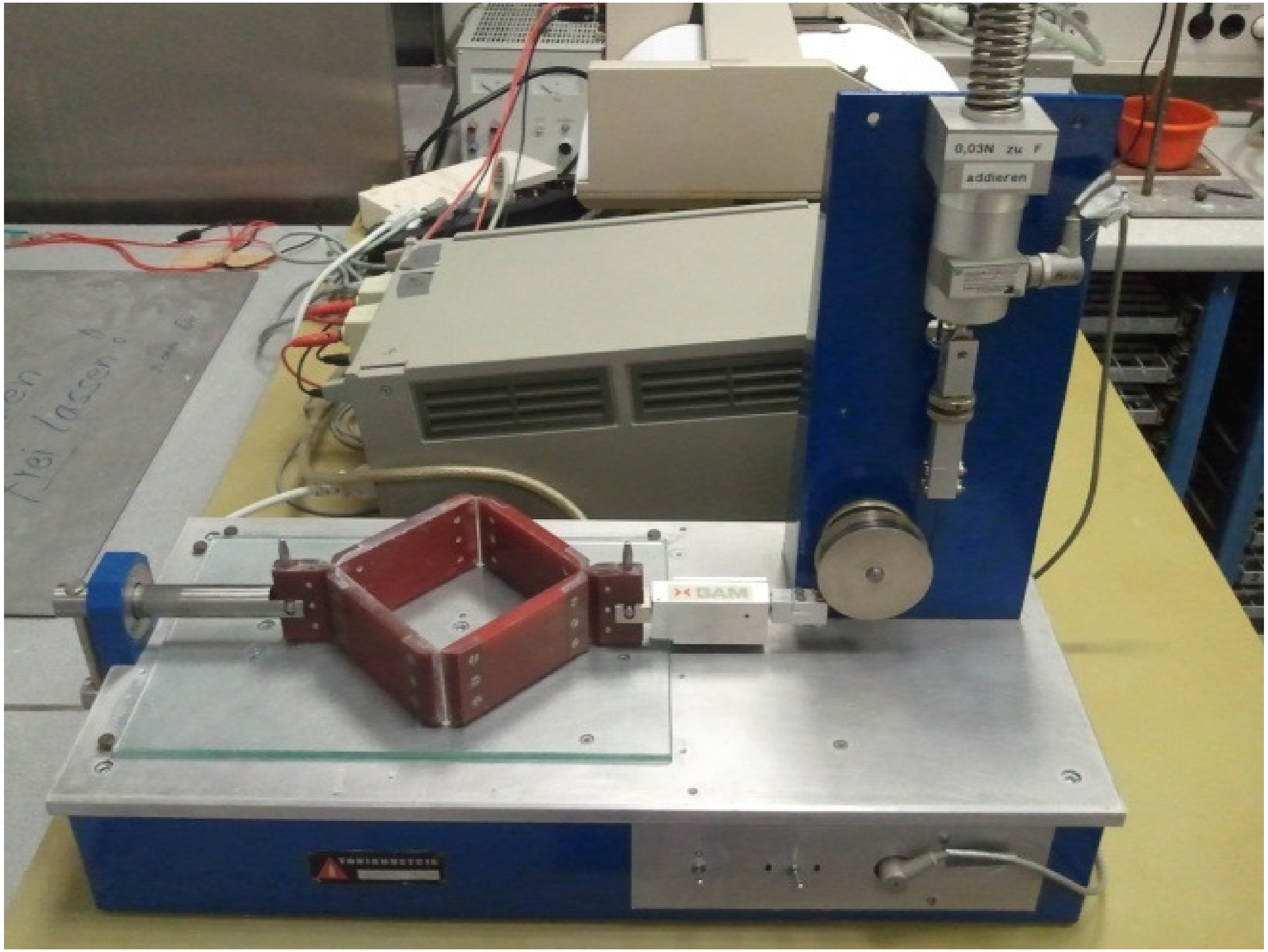


Modified version at the BAM:

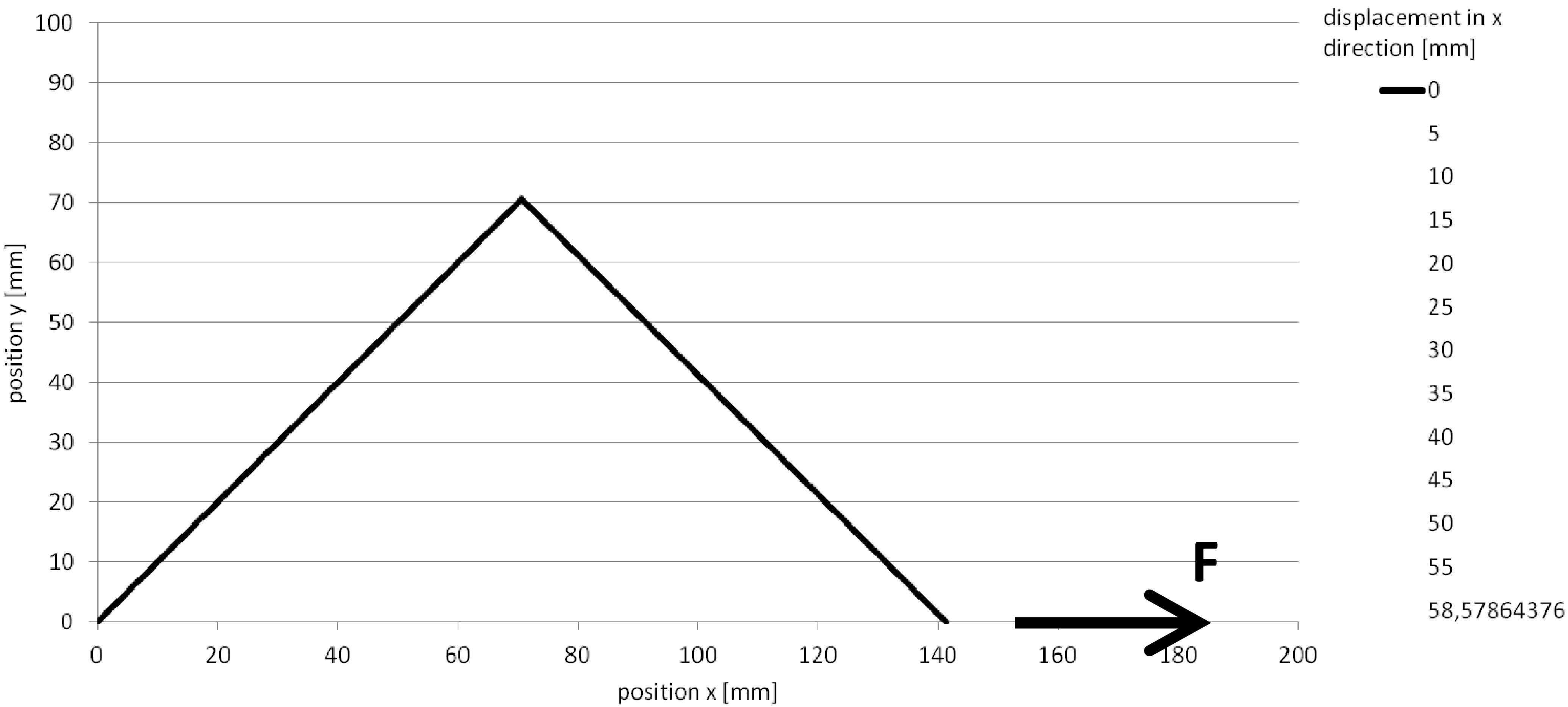
Updated with load cell and analog output signals for X-Y recorder in the 1980s/1990s

Recently updated for digital data logging

The Wuerpel-Device

Functional principle

Deformation from square shape to a rhombus shape



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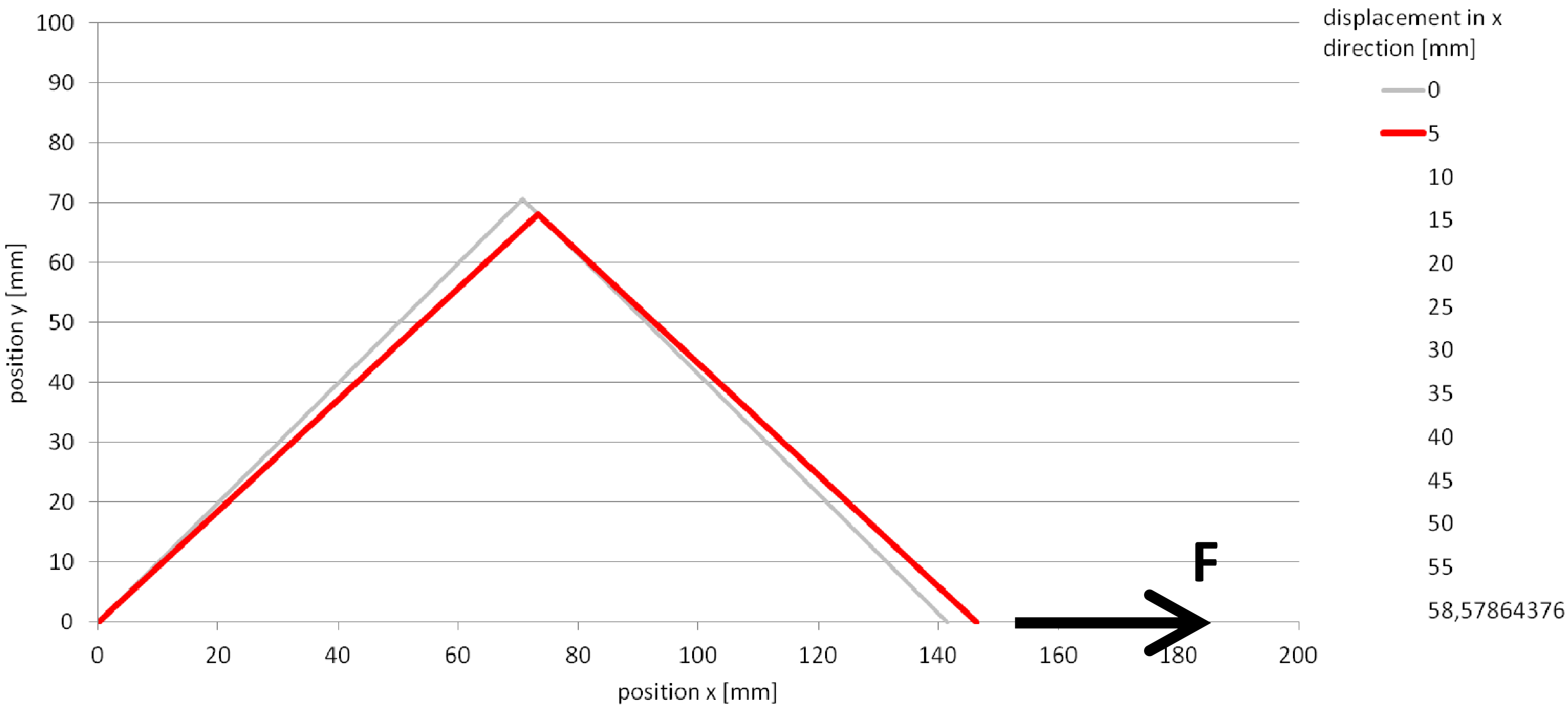

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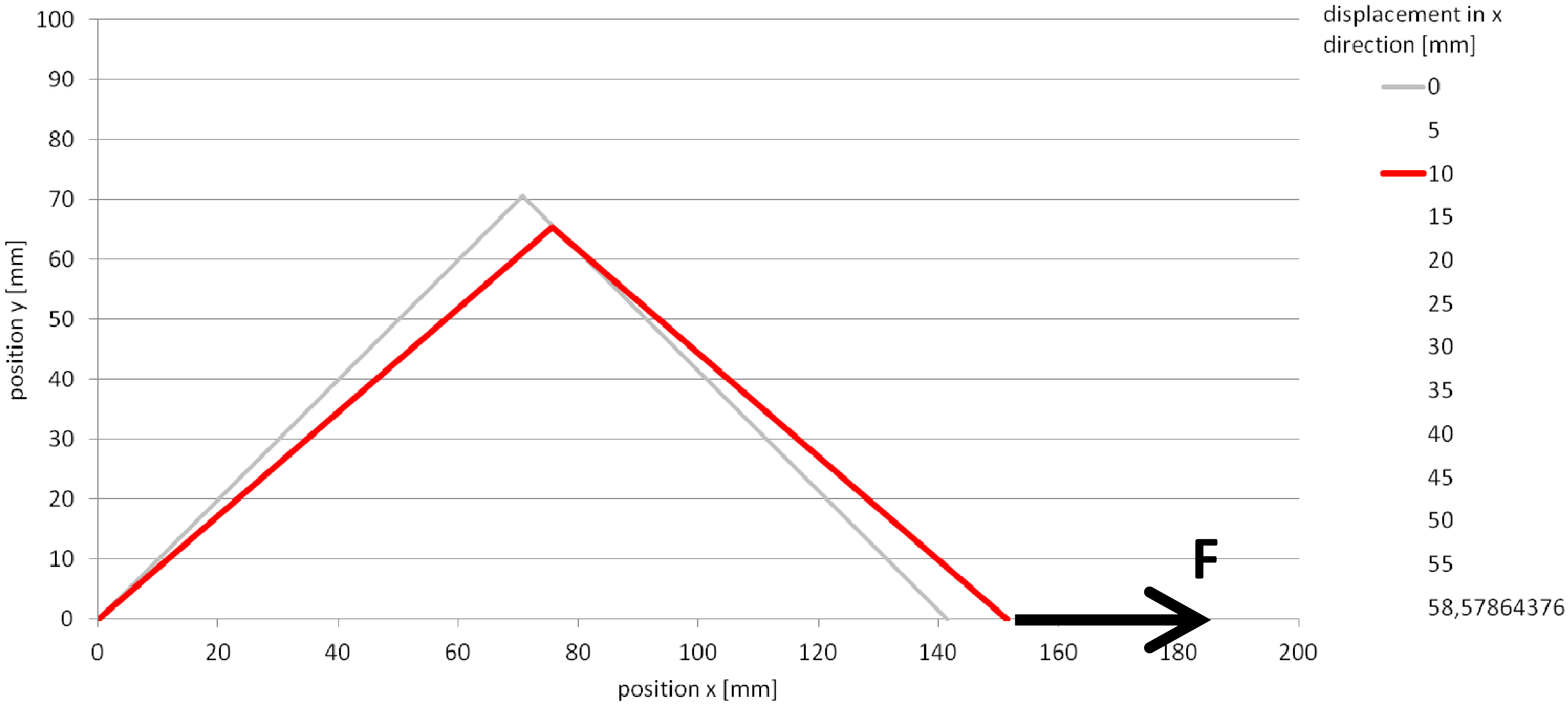

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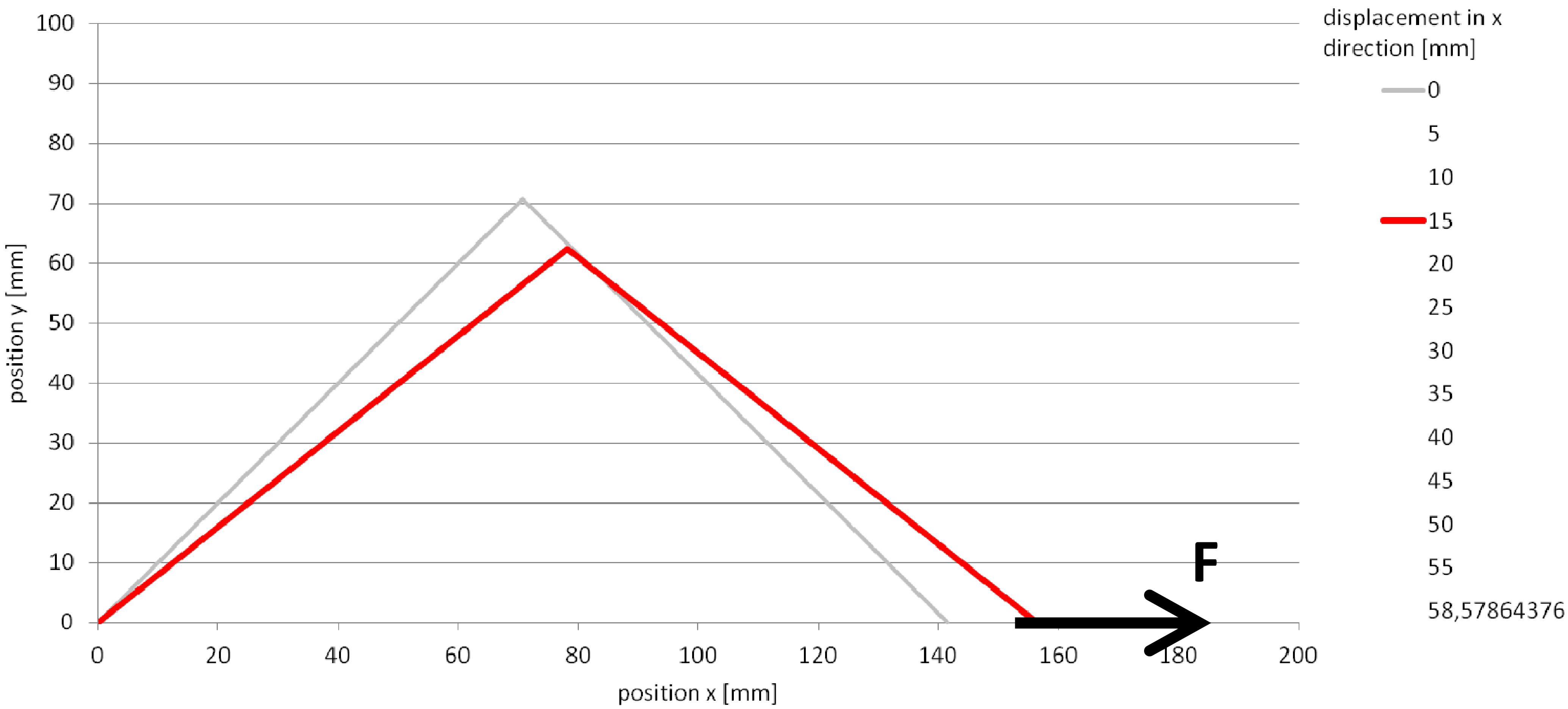

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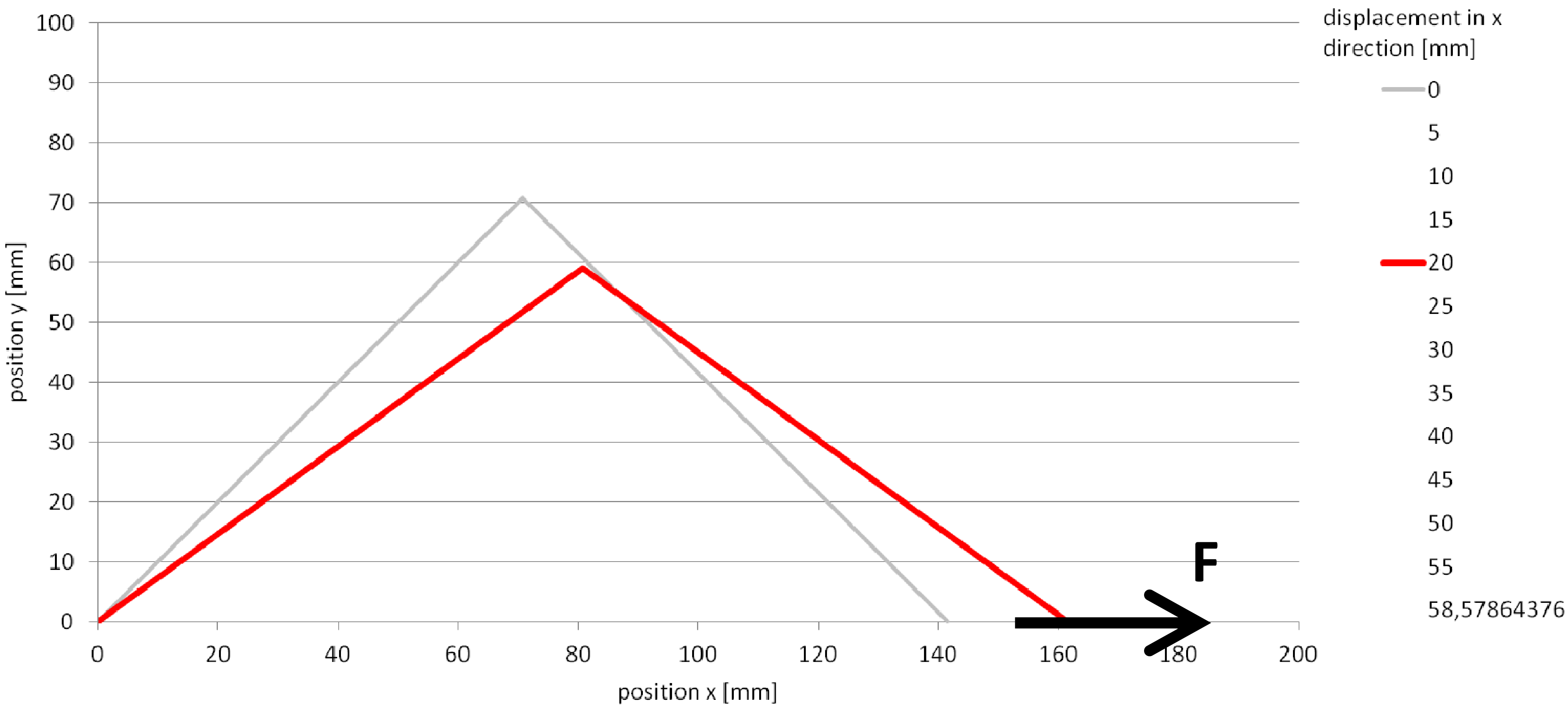

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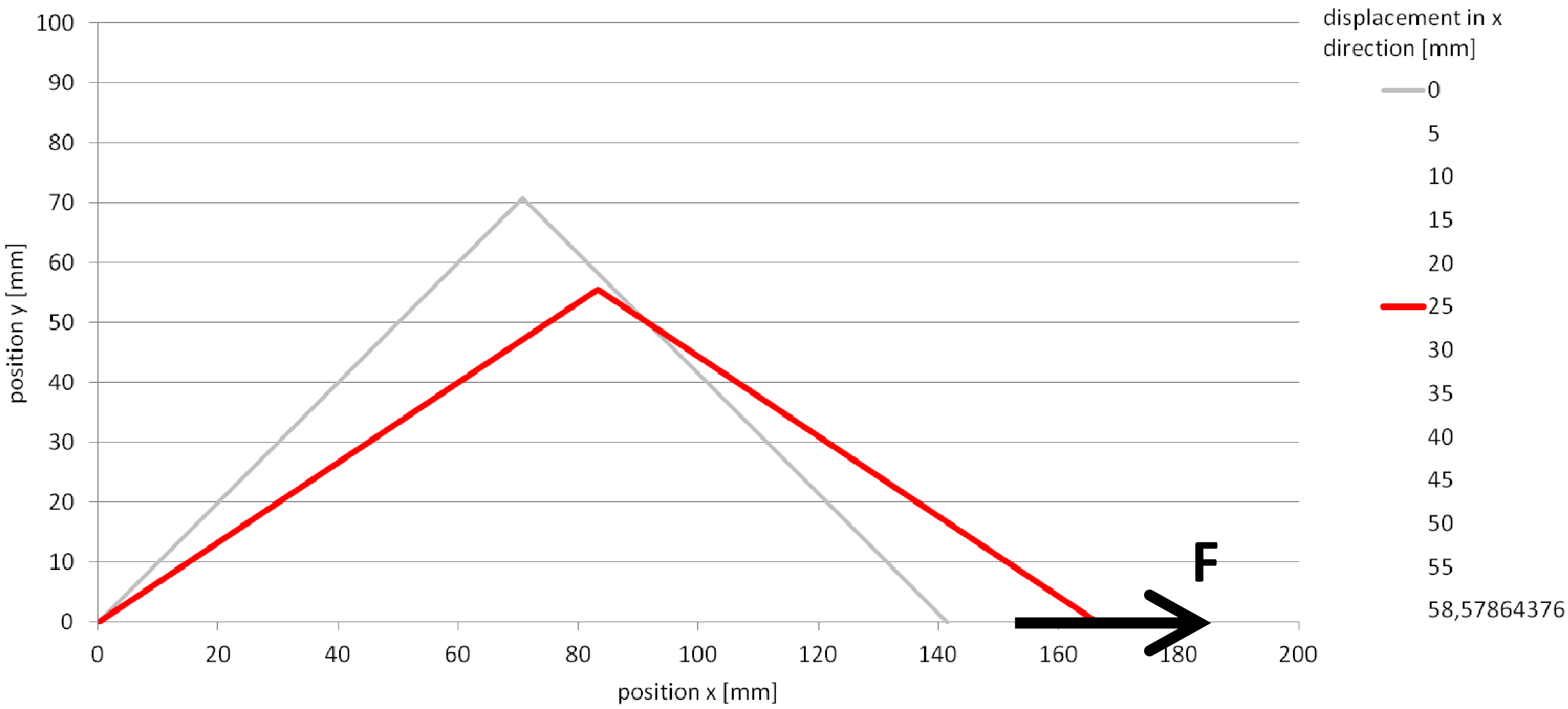

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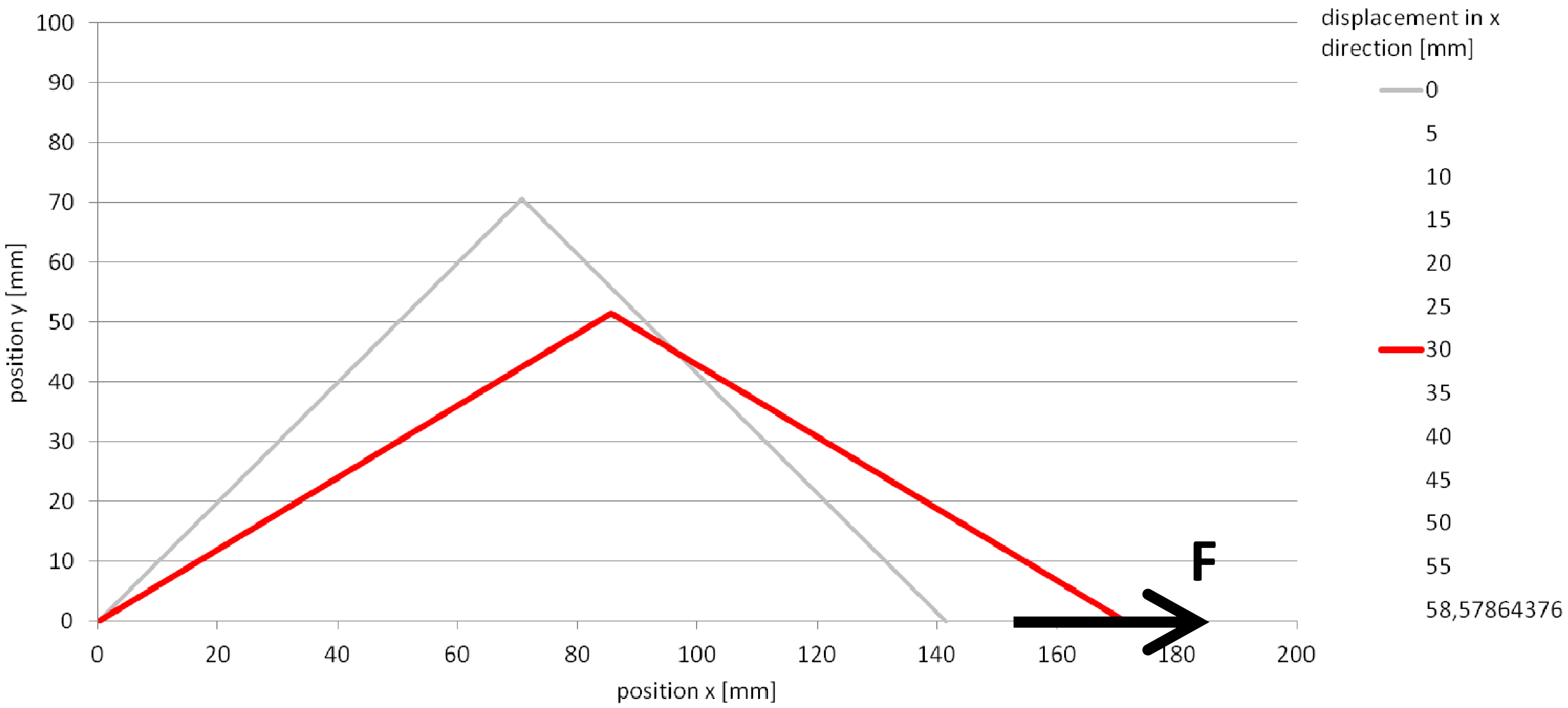

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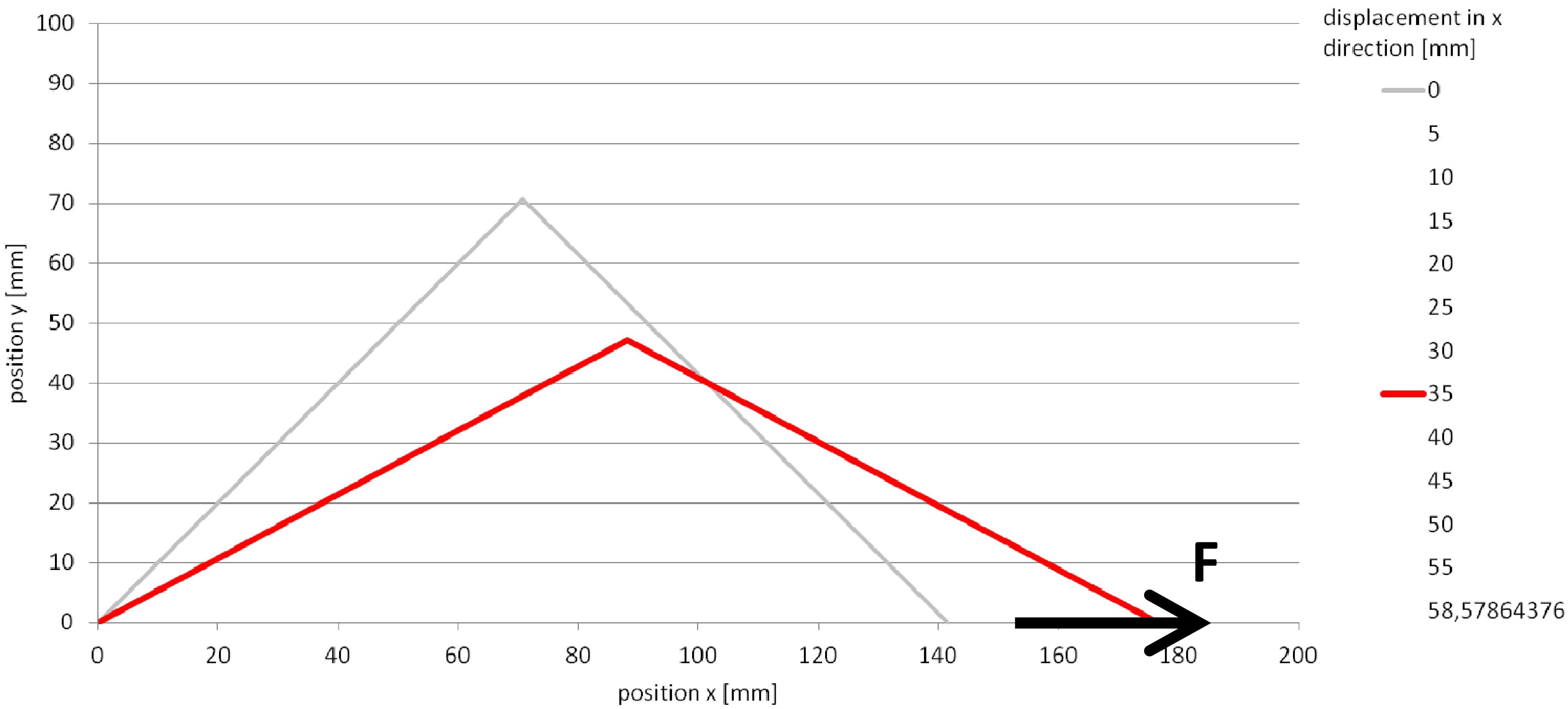

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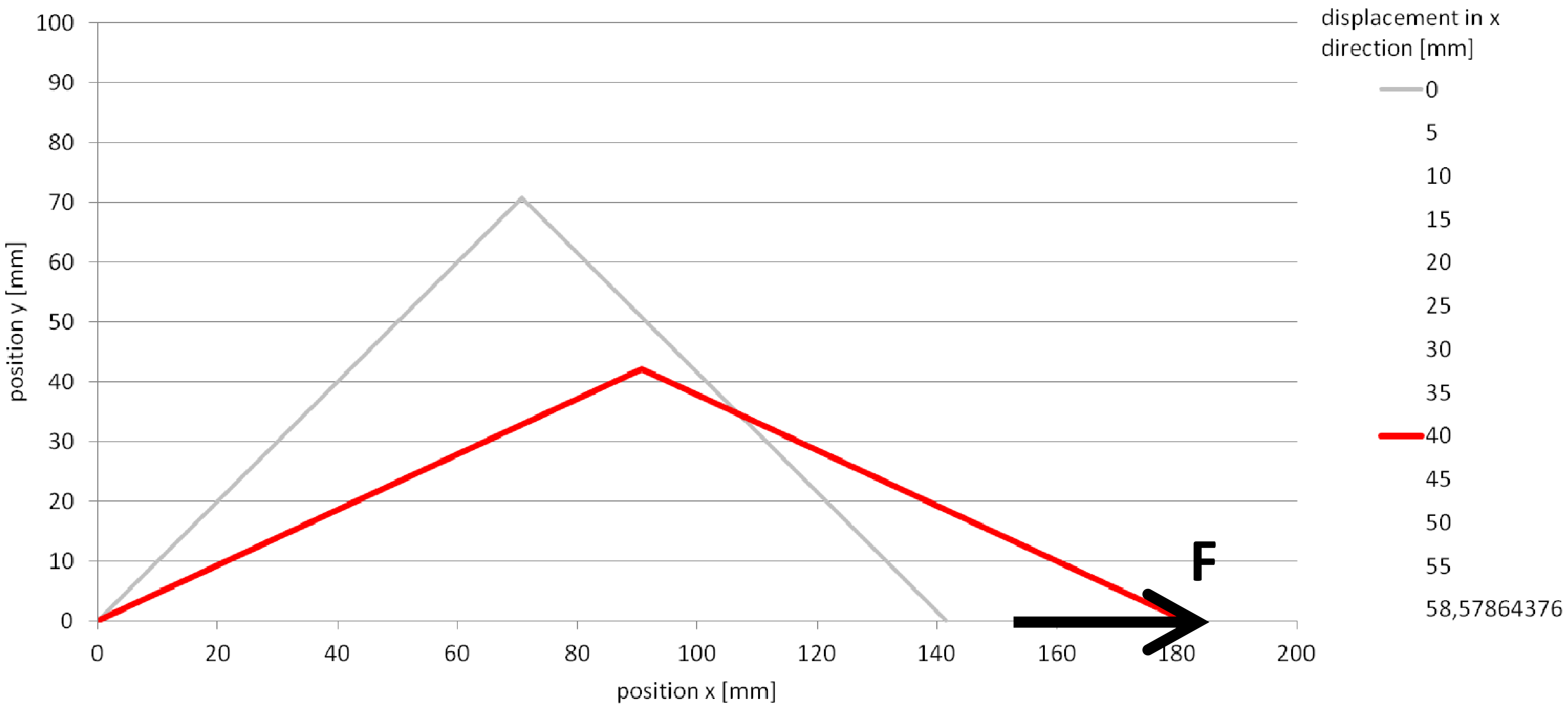

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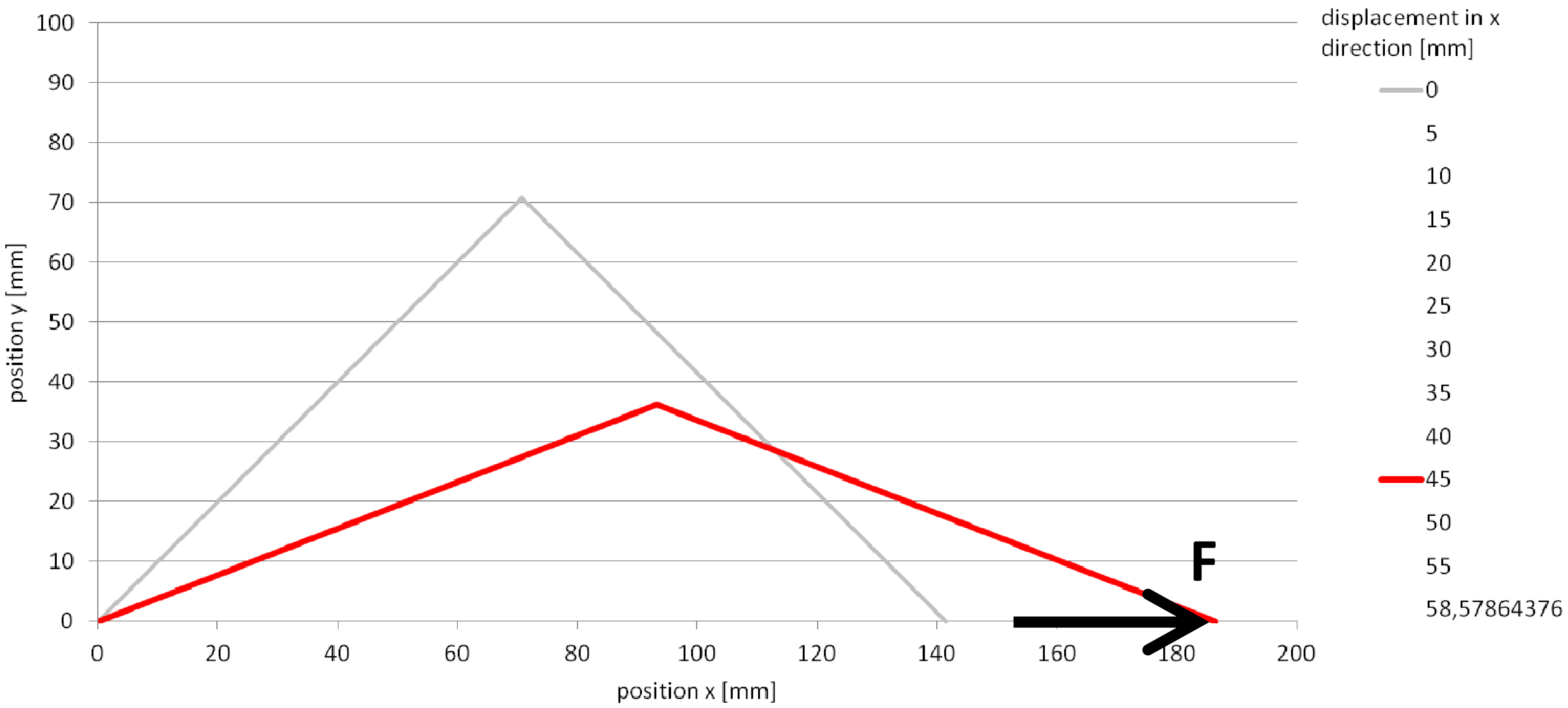

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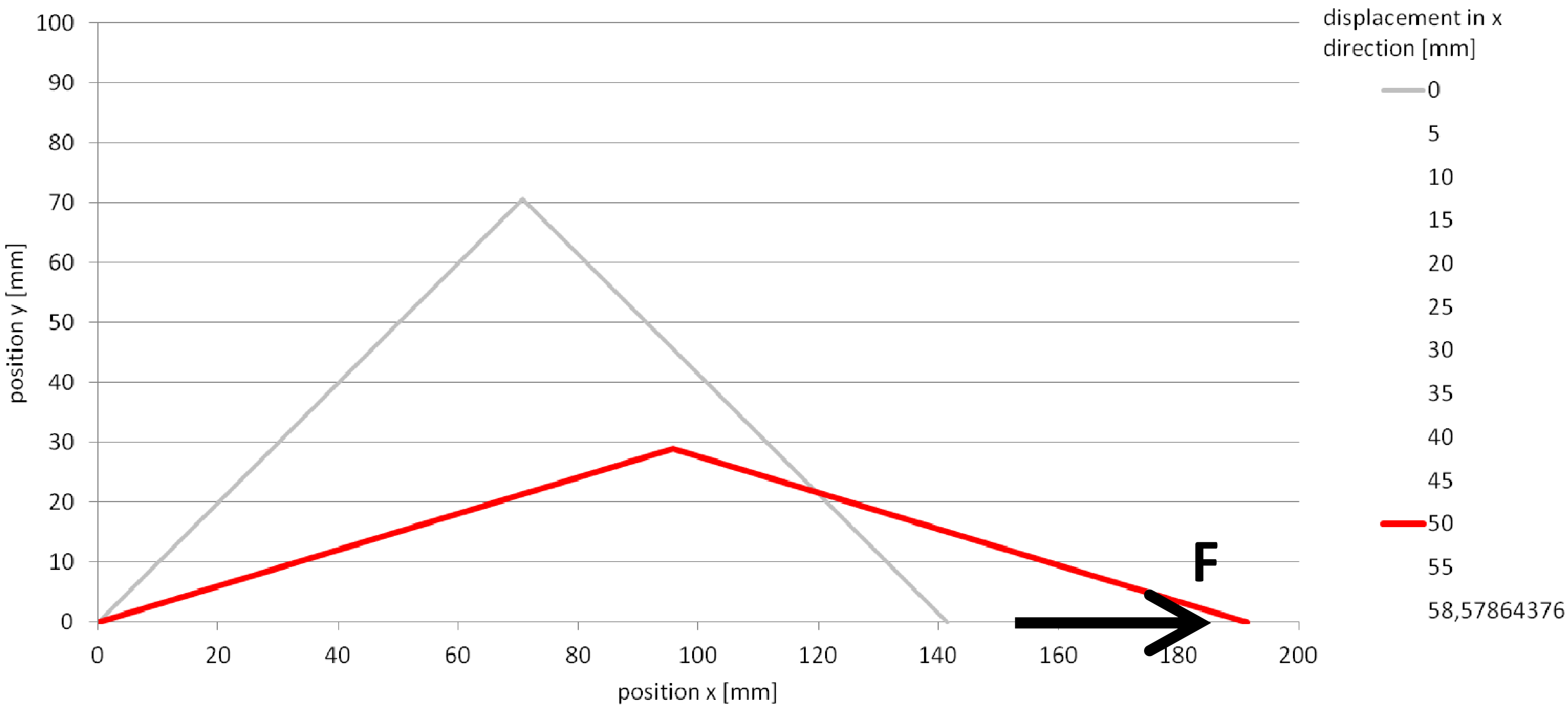

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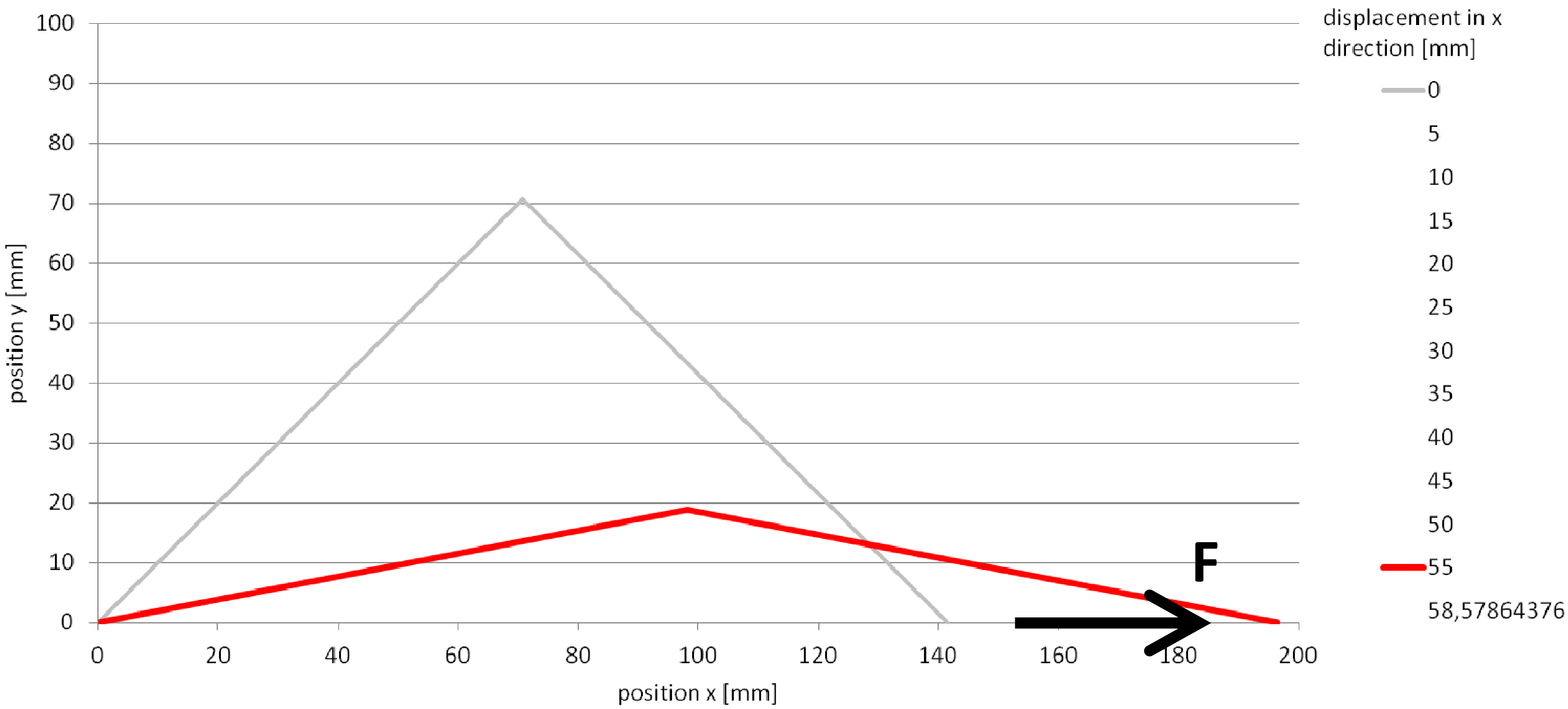

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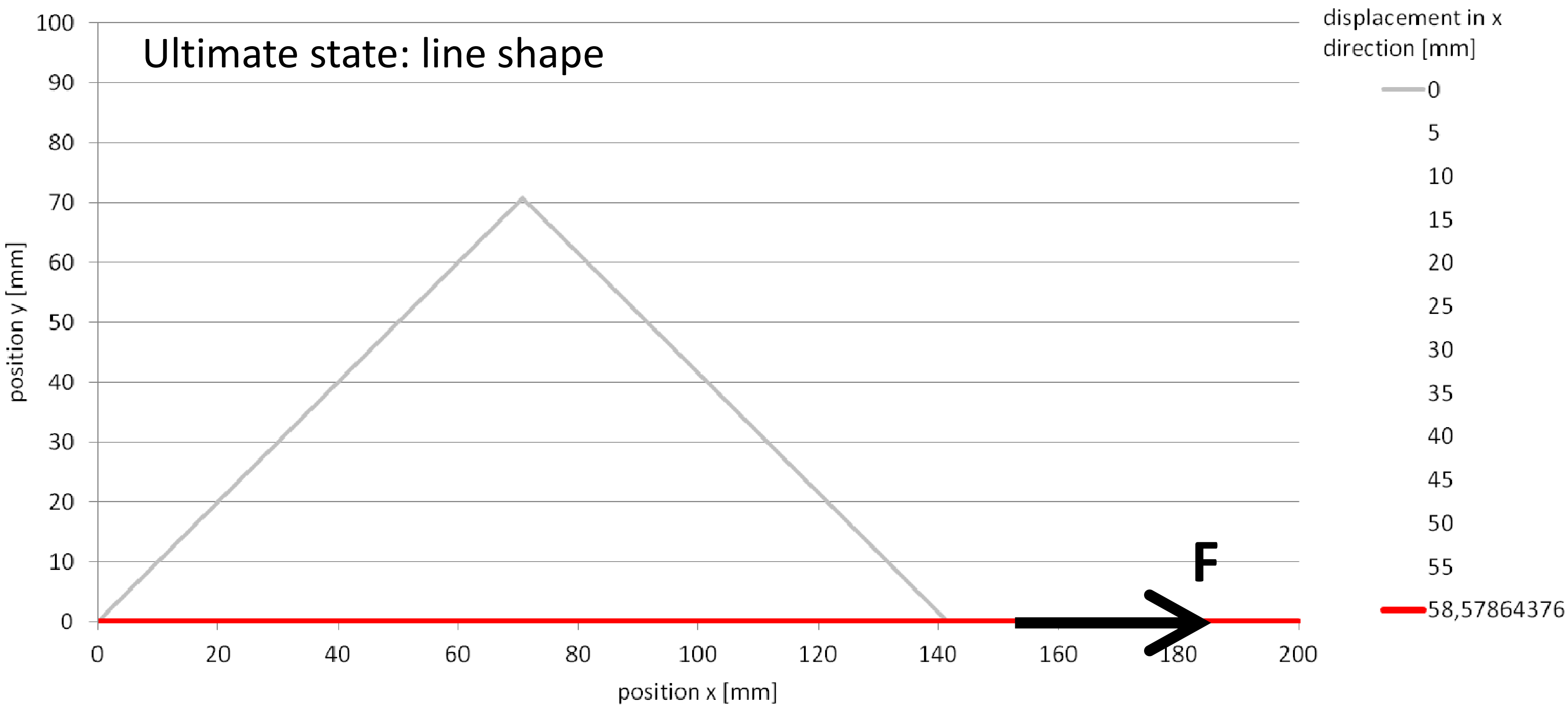

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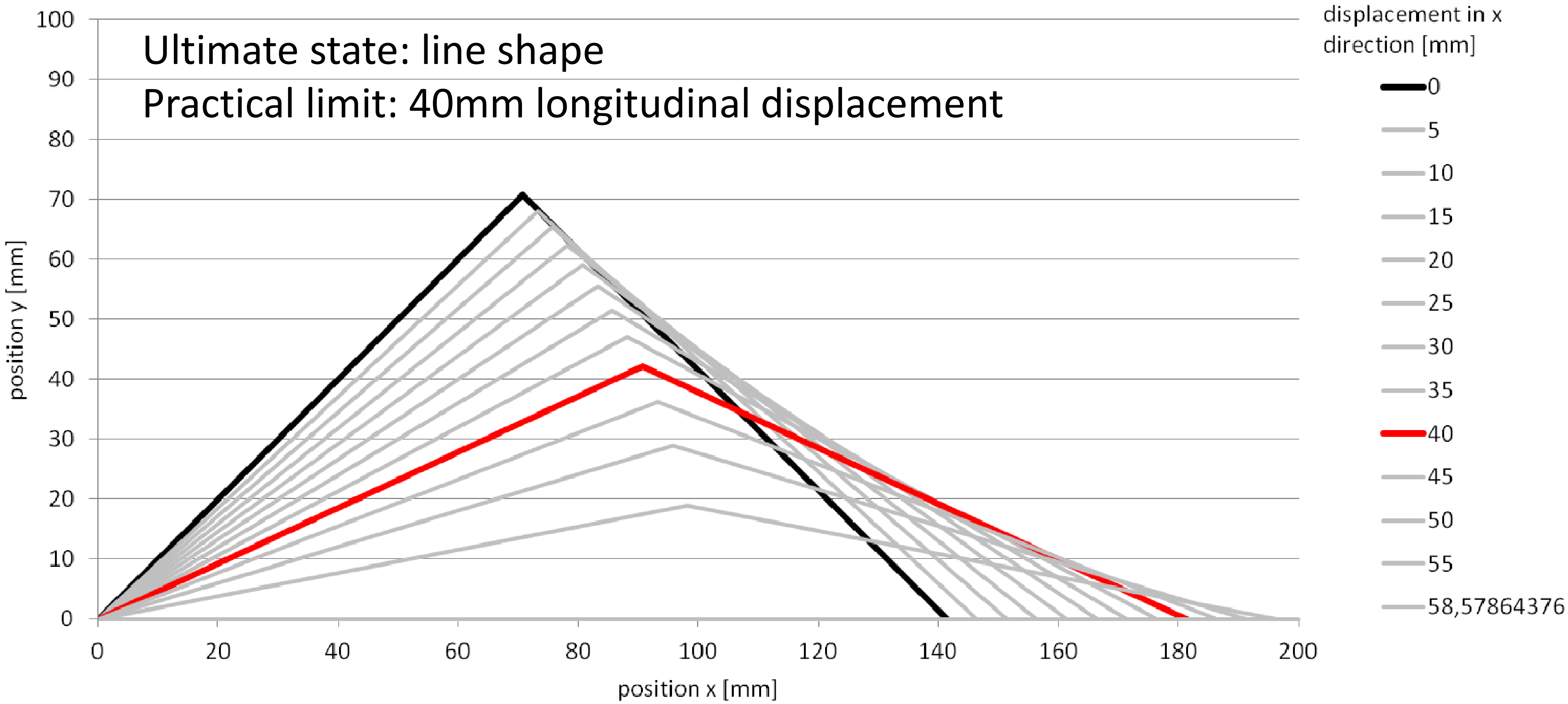

The Wuerpel-Device

Functional principle

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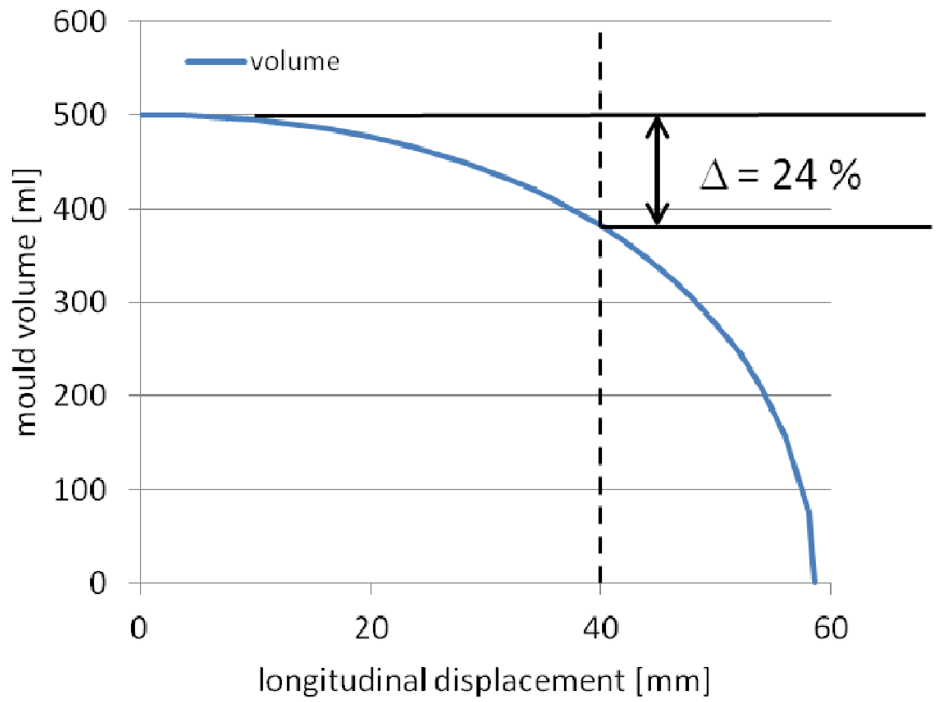
What happens to the mortar?

- It is squeezed/deformed
- due to volume change also squeezed out of the mould
- Impact is neither constant nor stationary



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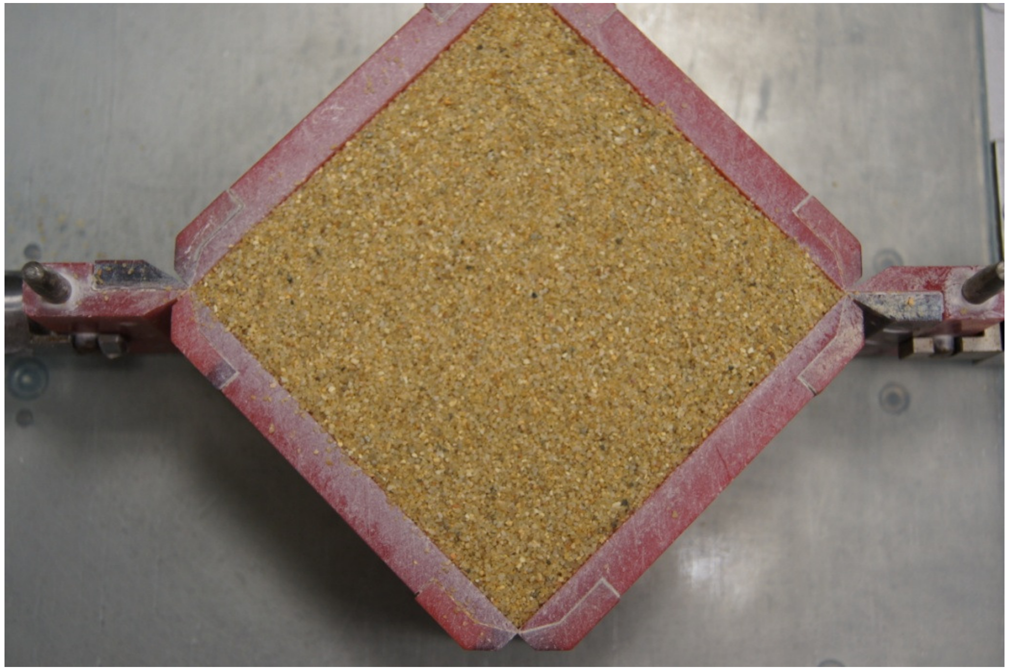

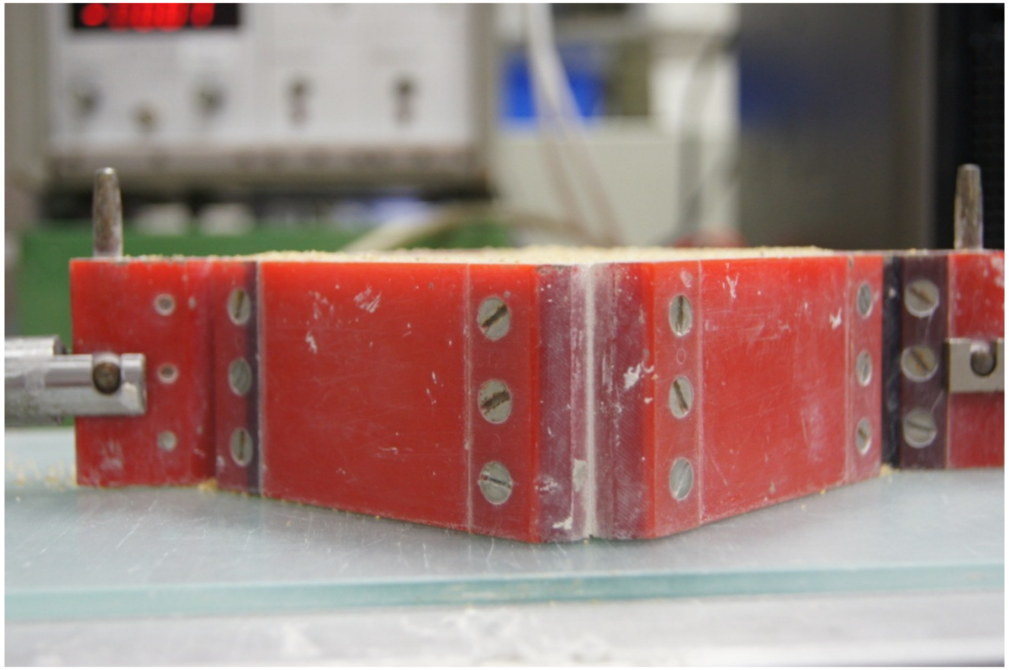

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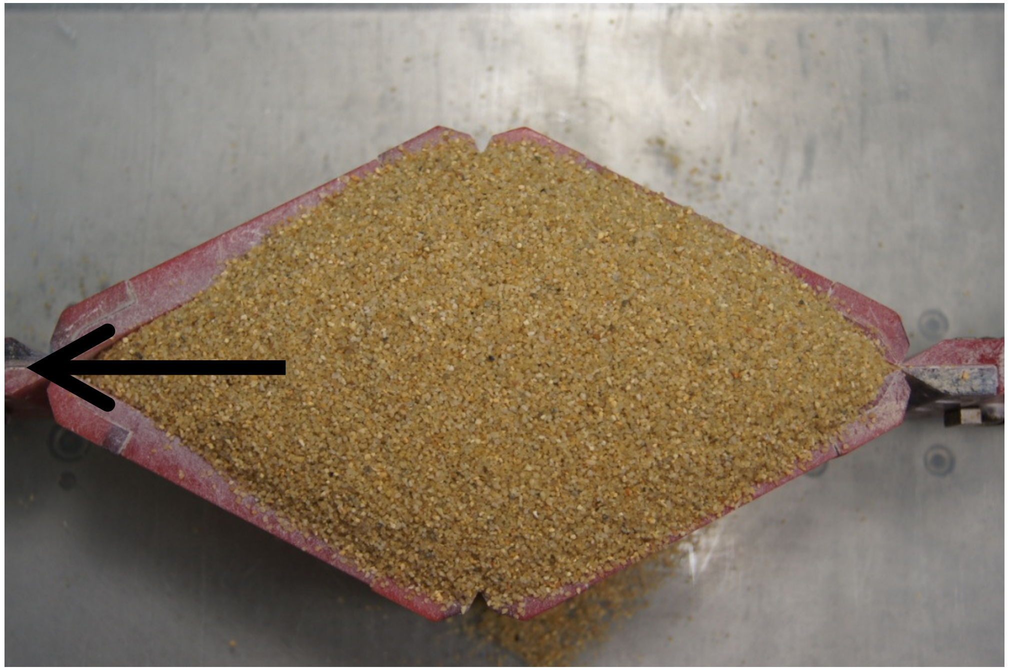
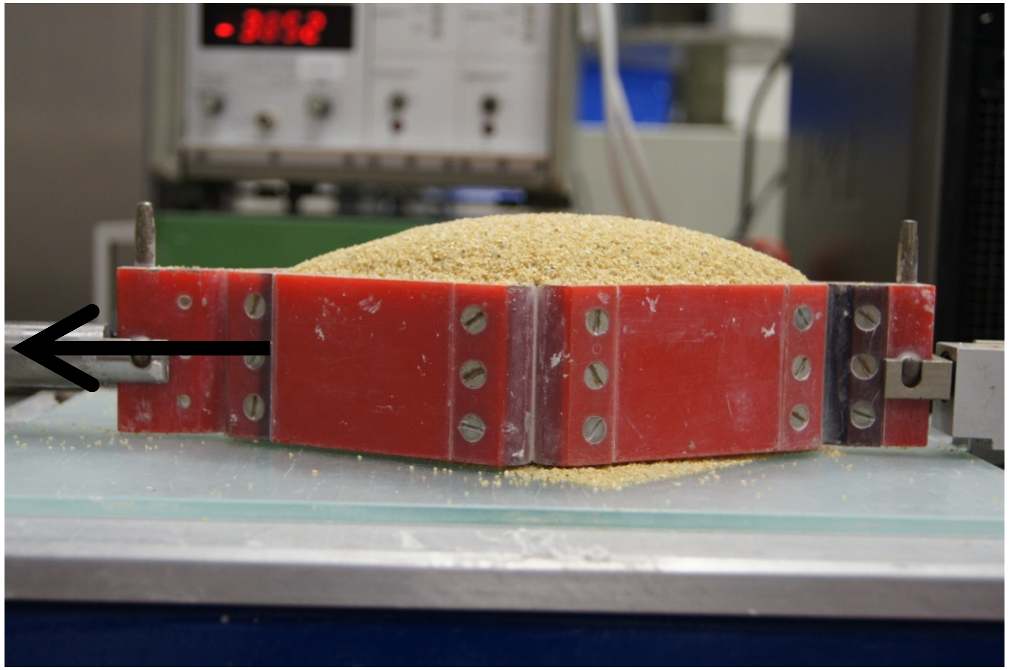

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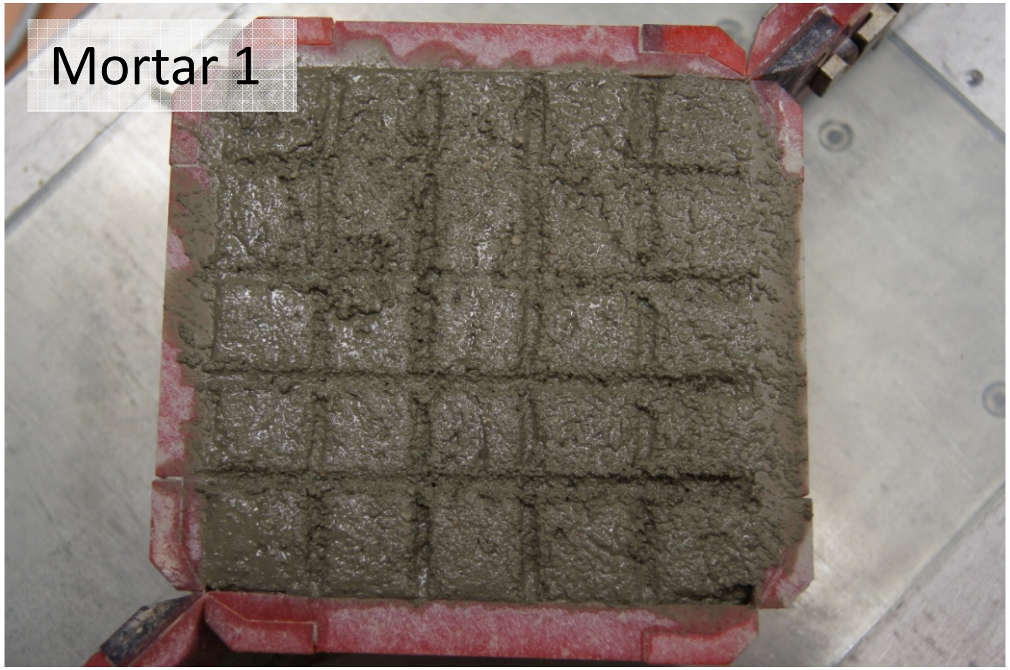

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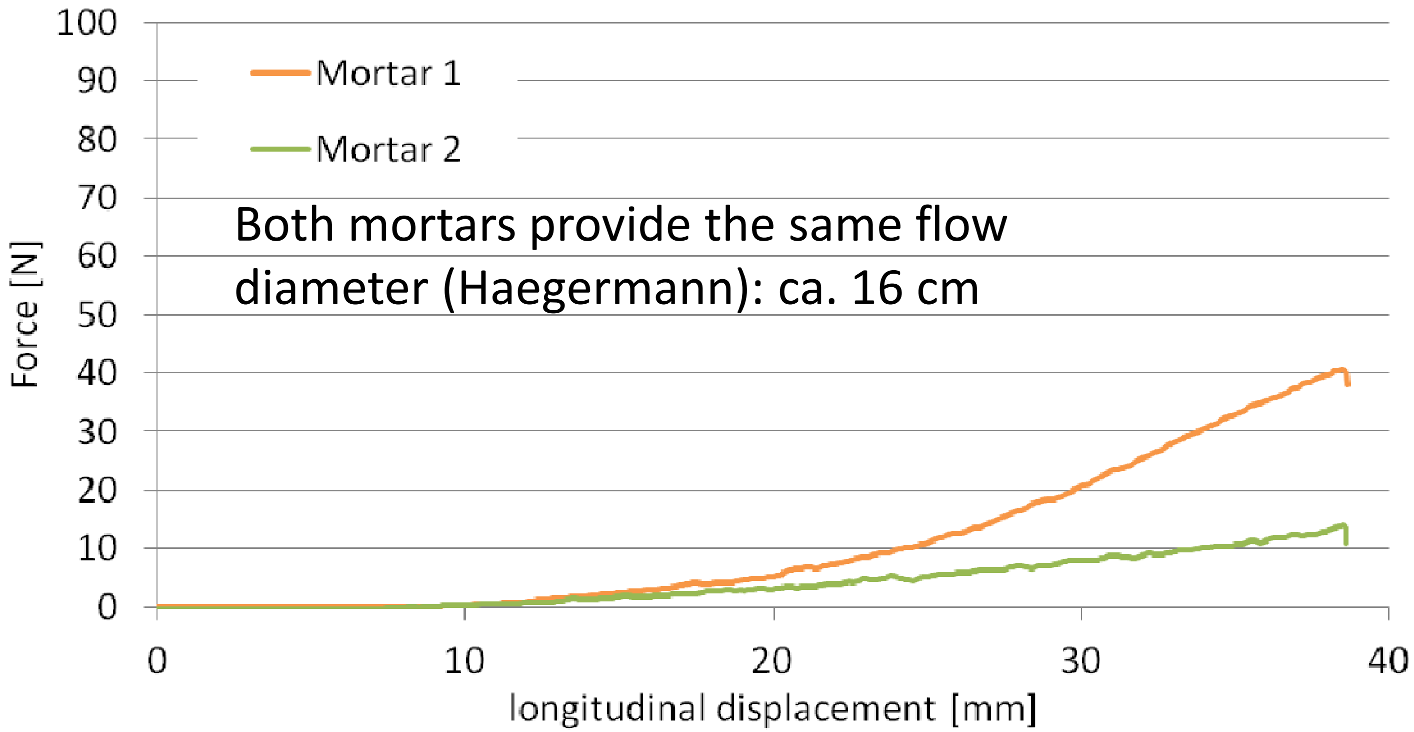

The Wuerpel-Device

Functional principle

Federal Institute for Materials Research and Testing

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- Impact is neither constant nor stationary
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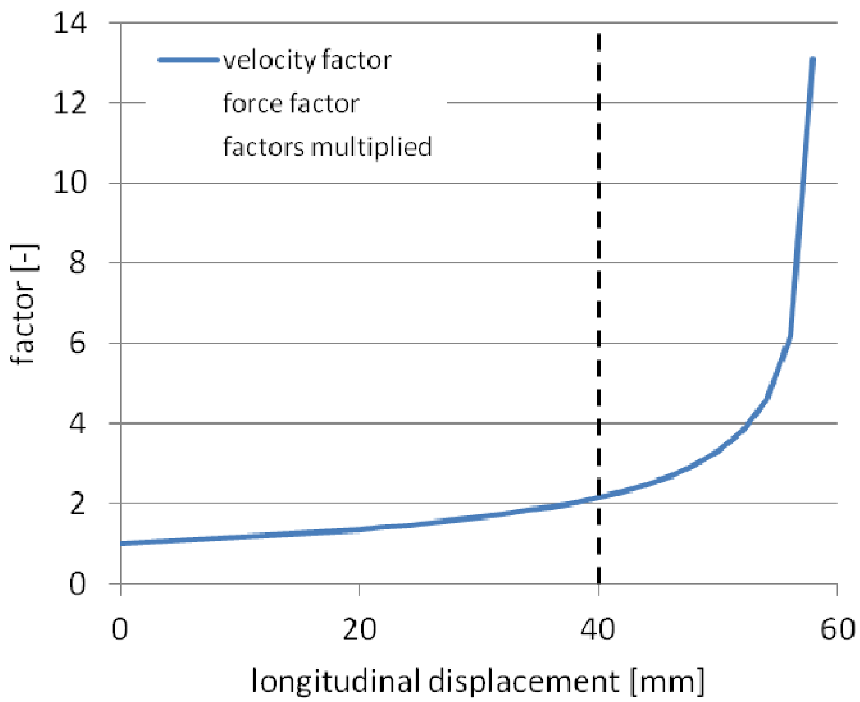
- Longitudinal force needed to maintain constant resulting transversal force increases also with ongoing deformation



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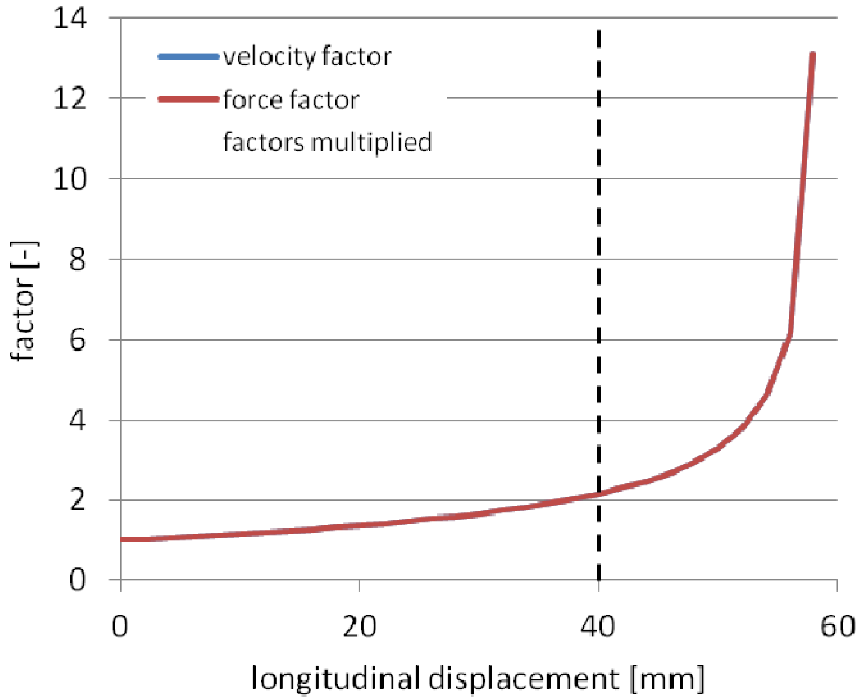

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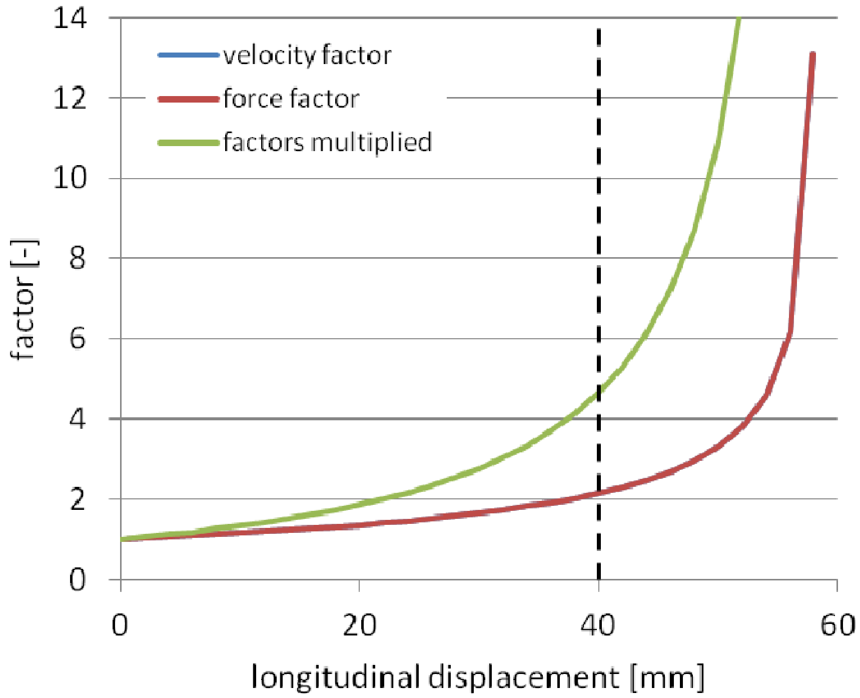

This explains the characteristic shape of the obtained measuring curves

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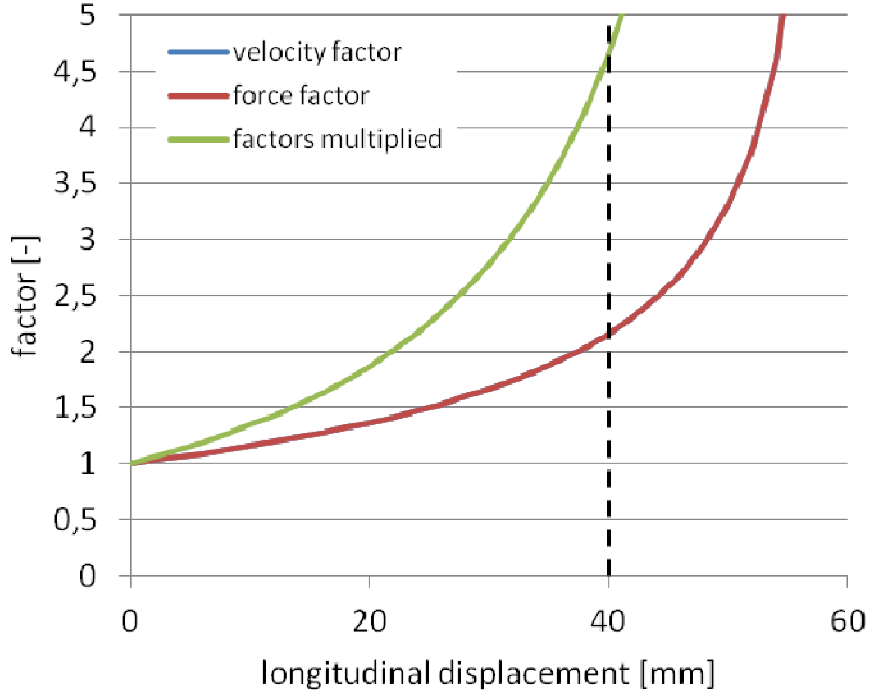

This explains the characteristic shape of the obtained measuring curves

Exemplary Experiments

Parameter Studies on Concrete Repair Mortar

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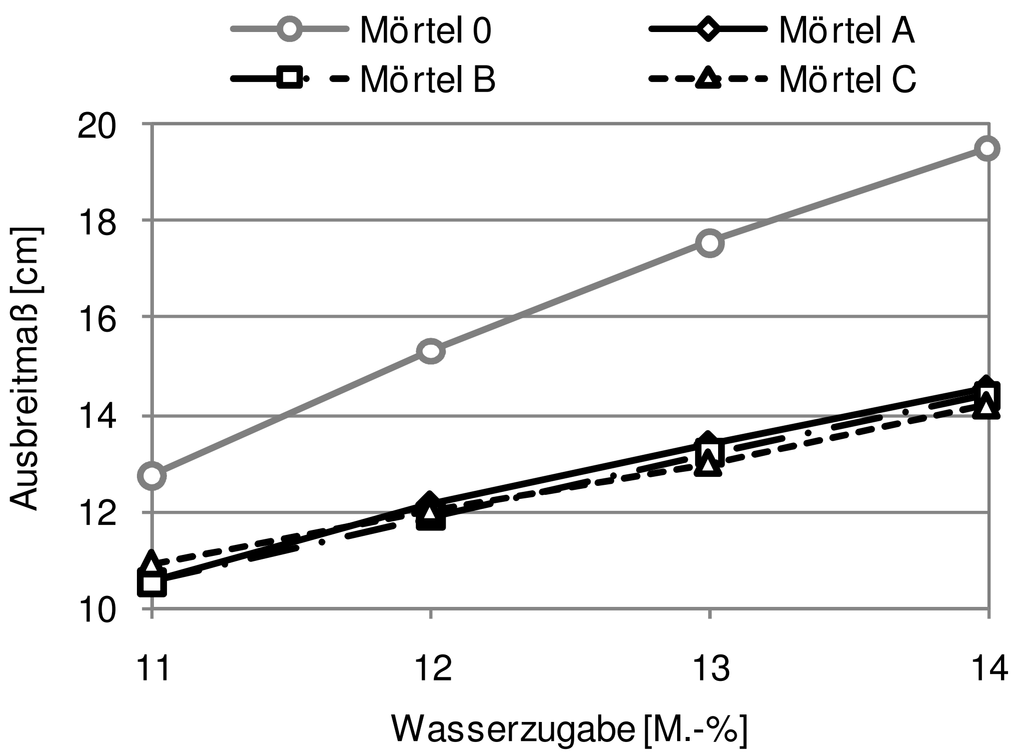
Use of different stabilizing agents

a) Mineral stabilizer: silica fume → Mortar A
b) Organic stabilizer: starch ether → Mortar B
c) Organic stabilizer: cellulose ether → Mortar C
d) Control mixture without stabilizer → Mortar 0



source: Ramge et al . 52. DAfStb Forschungskolloquium 2011

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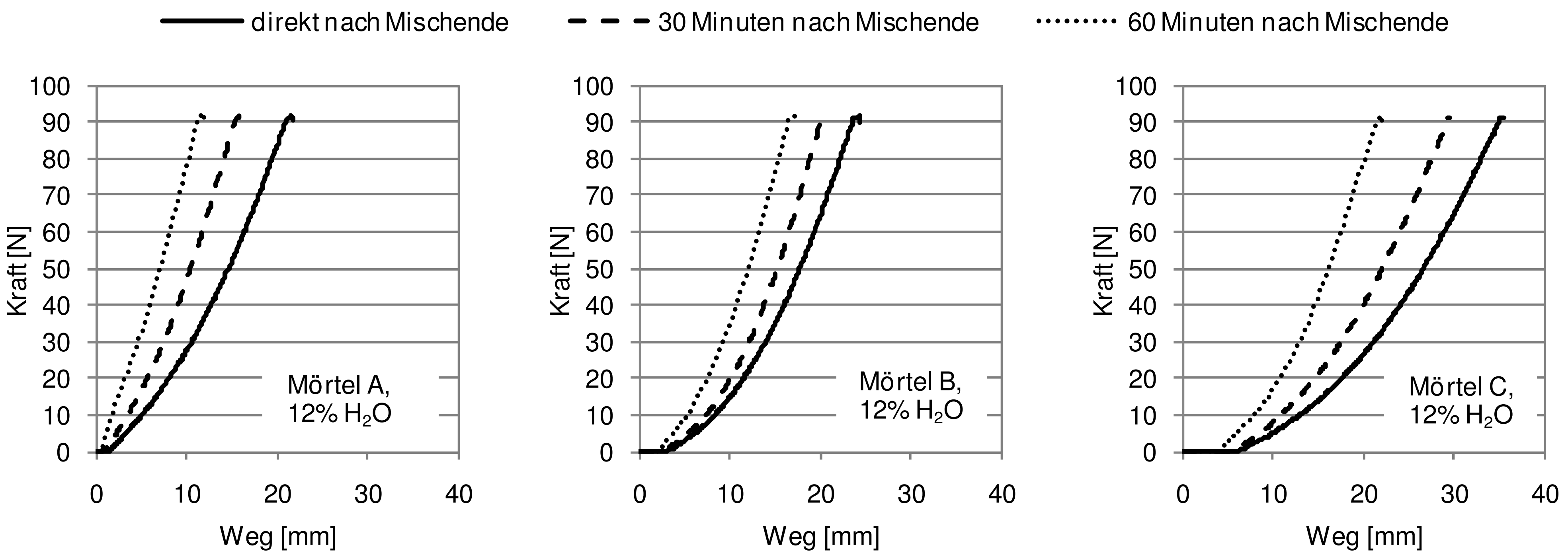
"Wuerpel results" for 12% water dosage



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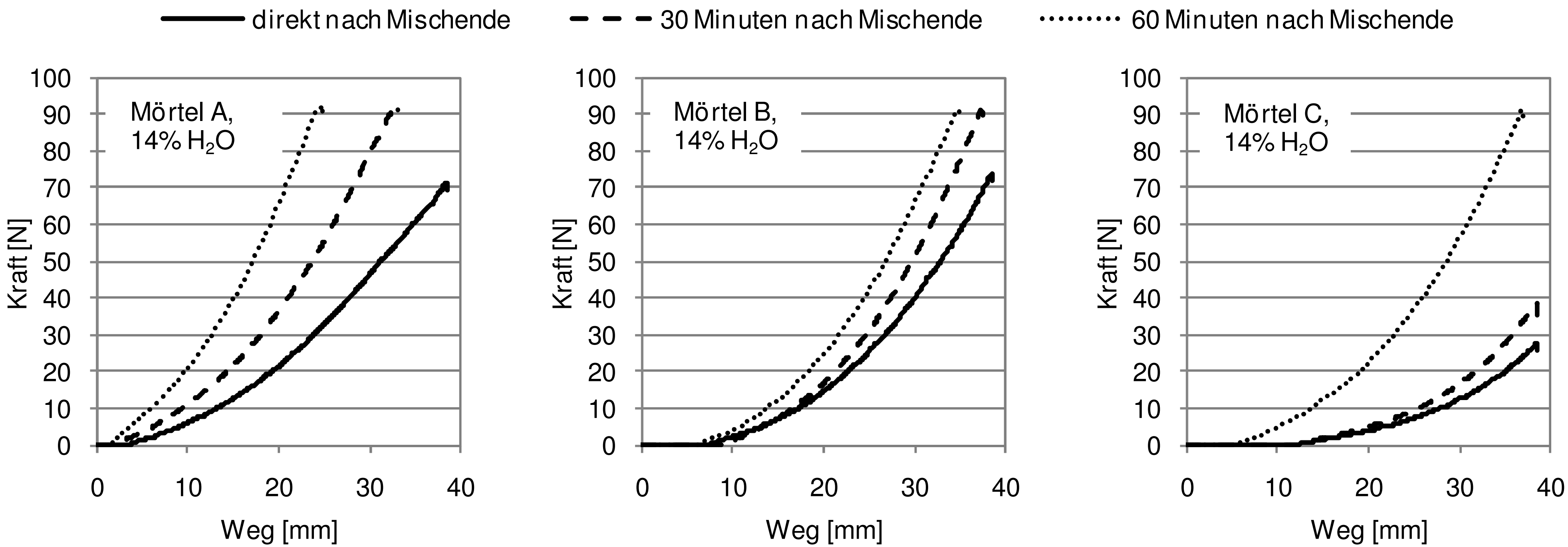
"Wuerpel results" for 14% water dosage



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Exemplary Experiments

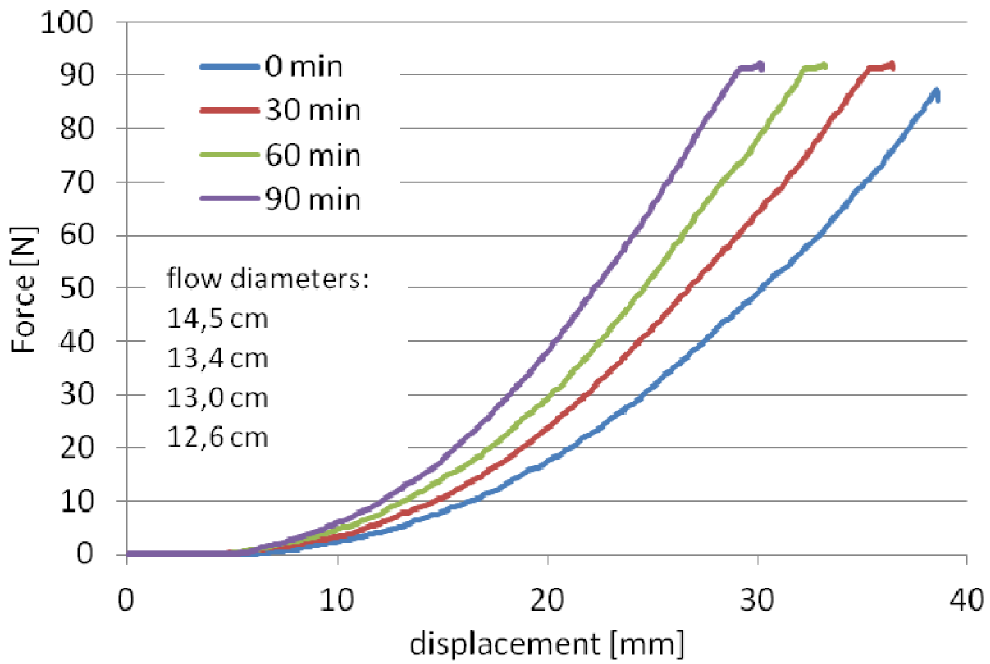
Parameter Studies on Repair Mortars for Natural Stone

Federal Institute for Materials Research and Testing

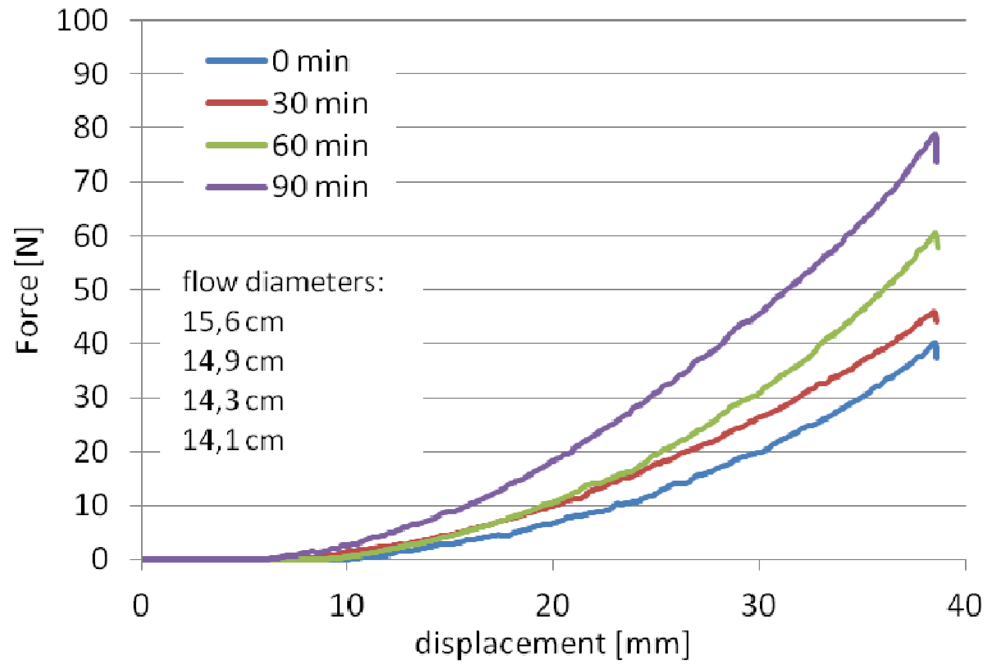
Appropriate only for certain consistency ranges

Parameter studies on polymer dispersion powder (different dosages)

Control mixture



Increasing polymer dosage



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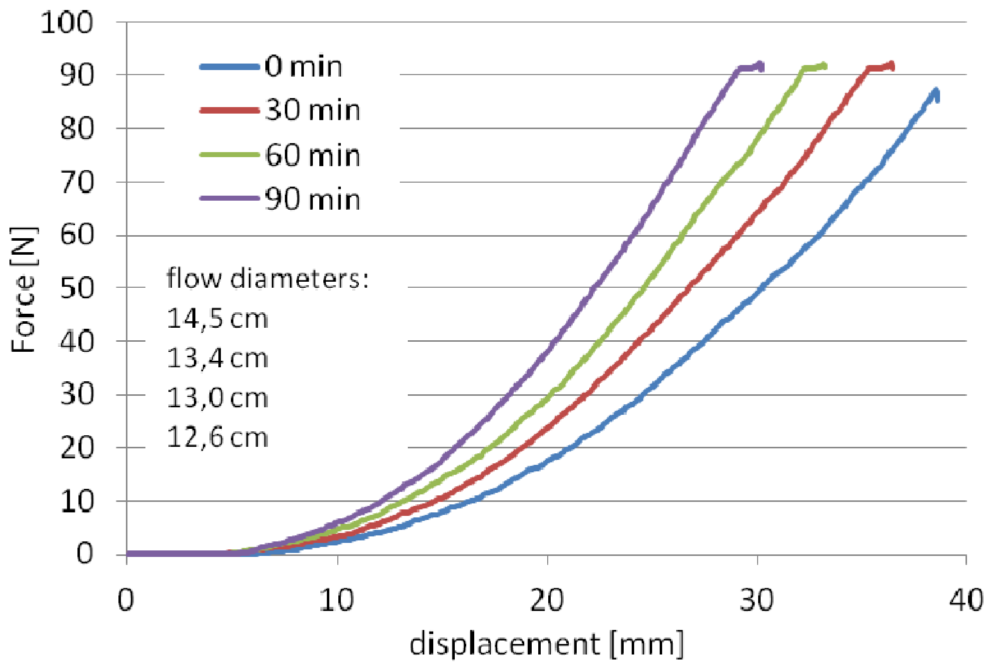

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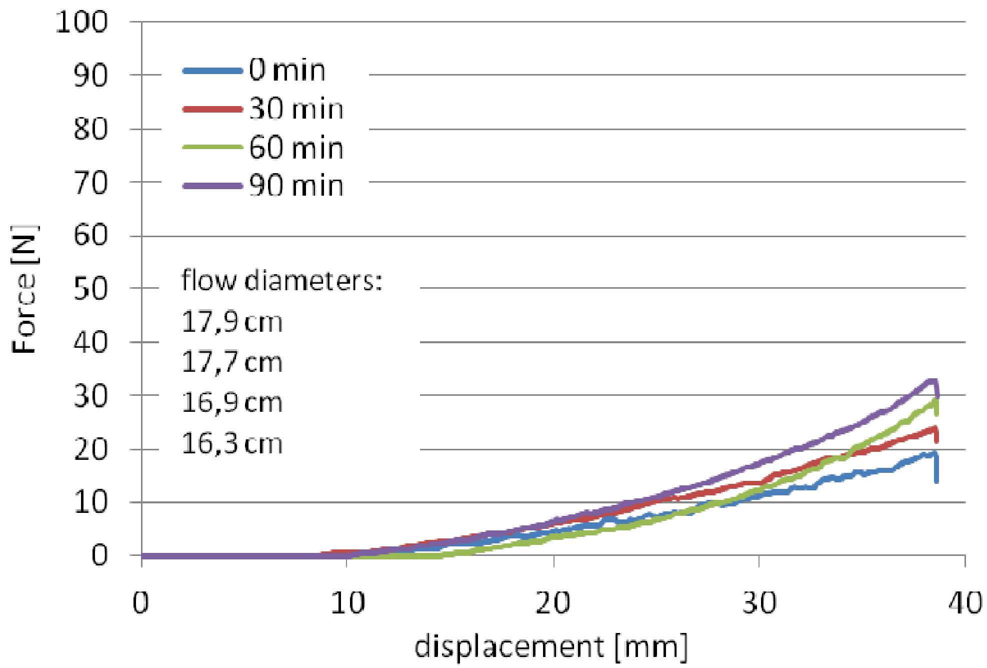

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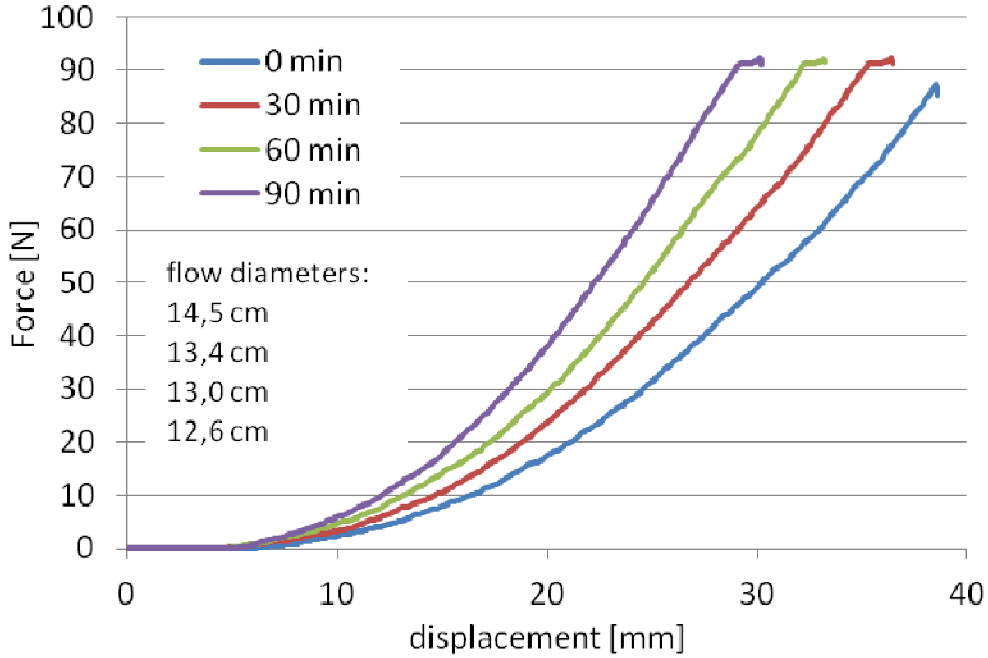
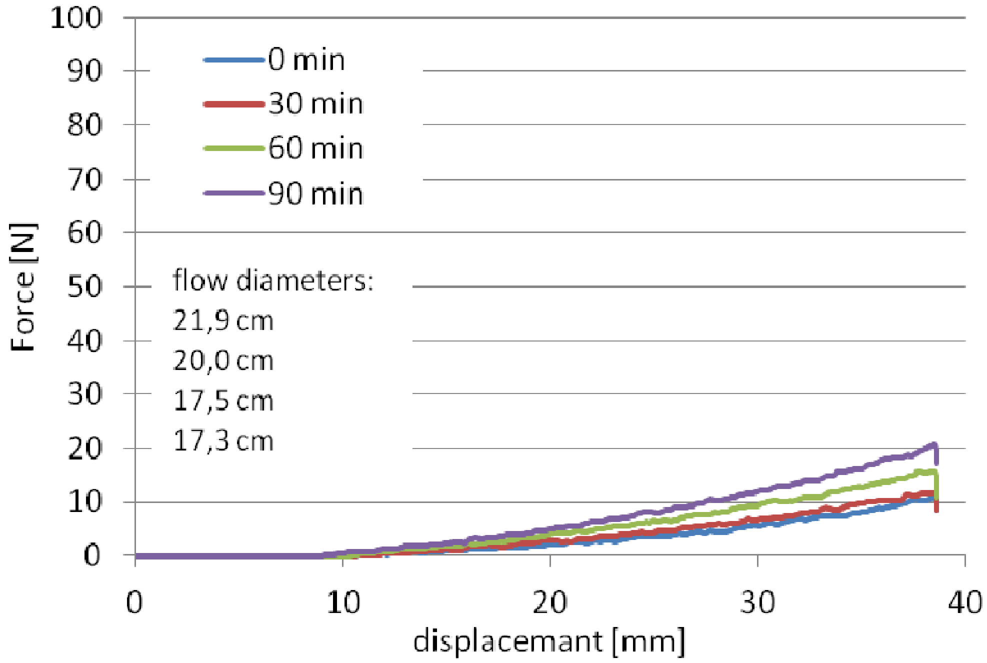


Increasing polymer dosage



Exemplary Experiments

Parameter Studies on Repair Mortars for Natural Stone

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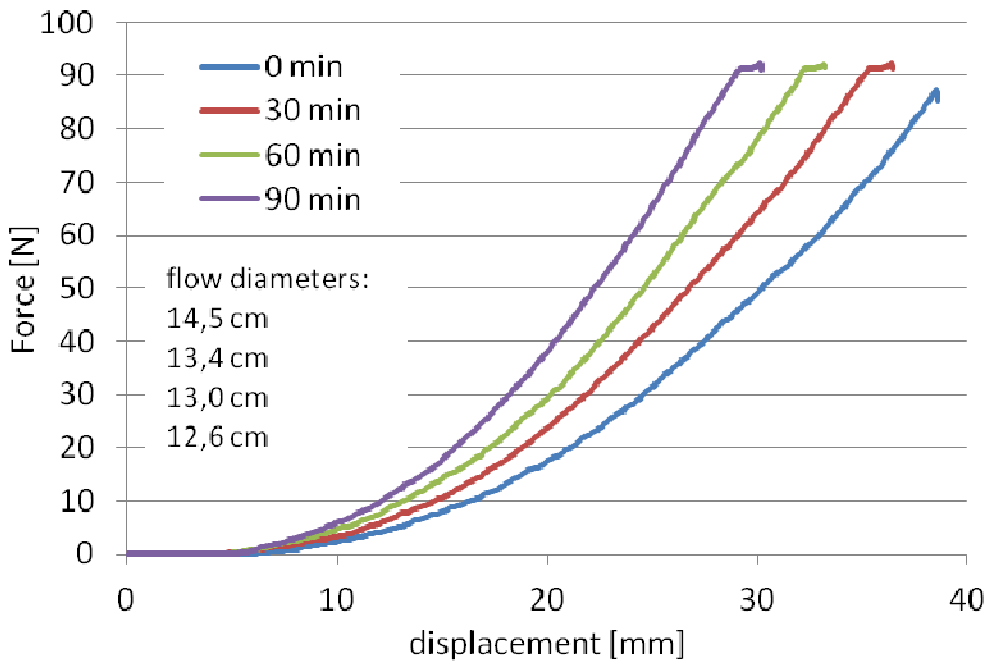
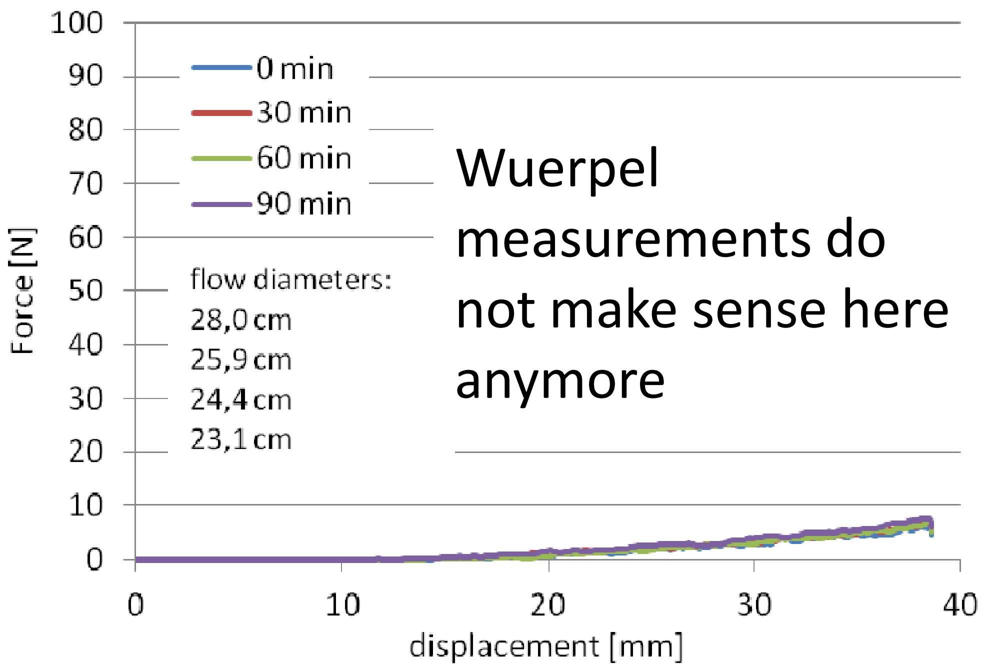
Appropriate only for certain consistency ranges

Parameter studies on polymer dispersion powder (different dosages)

Control mixture



Increasing polymer dosage



Exemplary Experiments

Parameter Studies on Repair Mortars for Natural Stone

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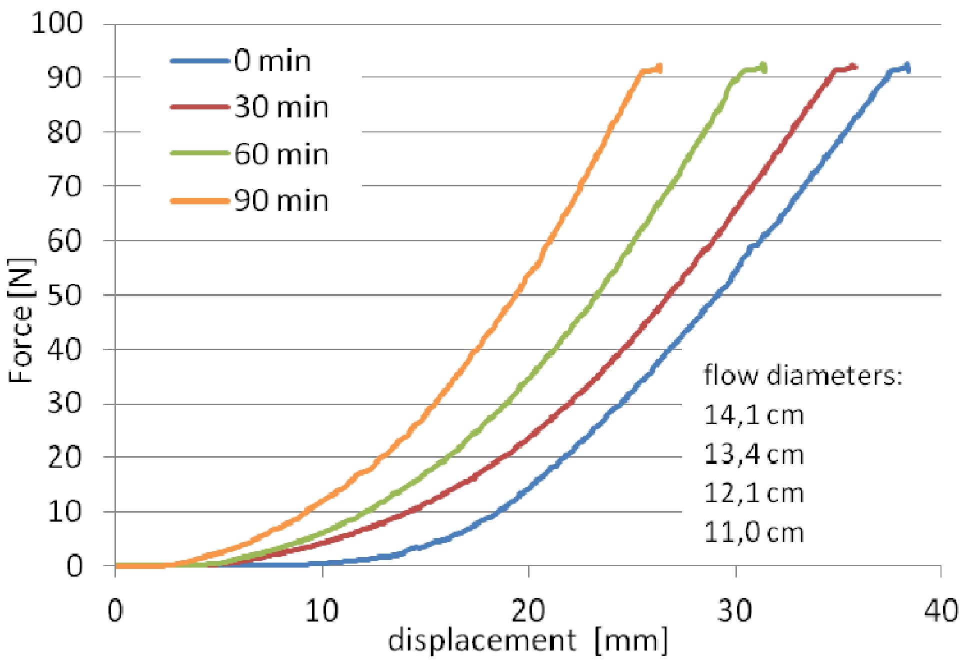
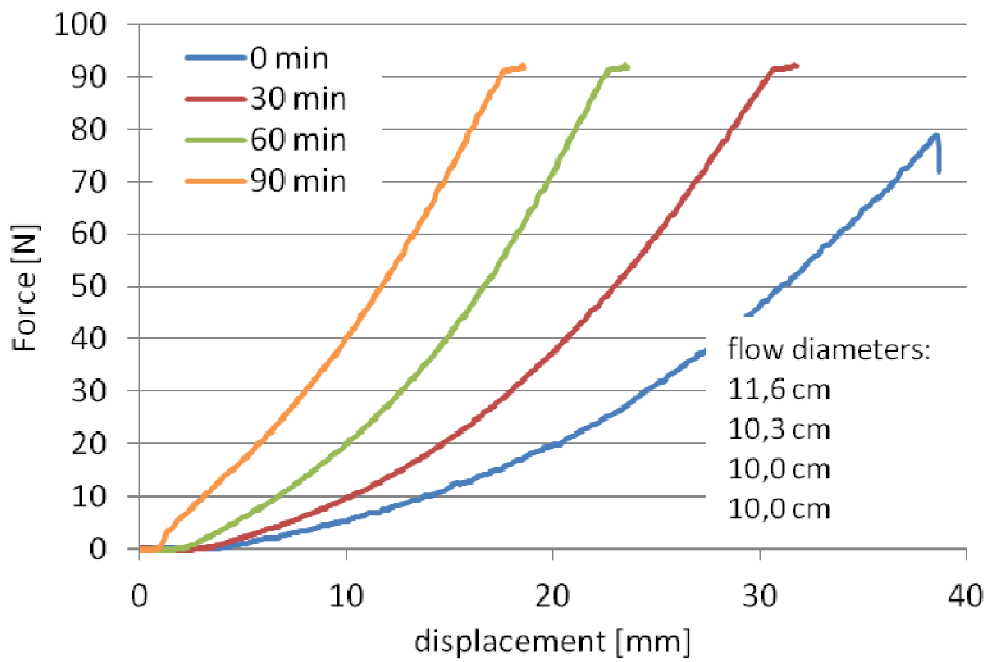
Sometimes very sensitive in areas where the flow diameter does not change much

Parameter studies casein dosage in repair mortar for cultural heritage

Control mixture



Mixture containing casein



Exemplary Experiments

Parameter Studies on Repair Mortars for Natural Stone

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Sometimes very sensitive in areas where the flow diameter does not change much

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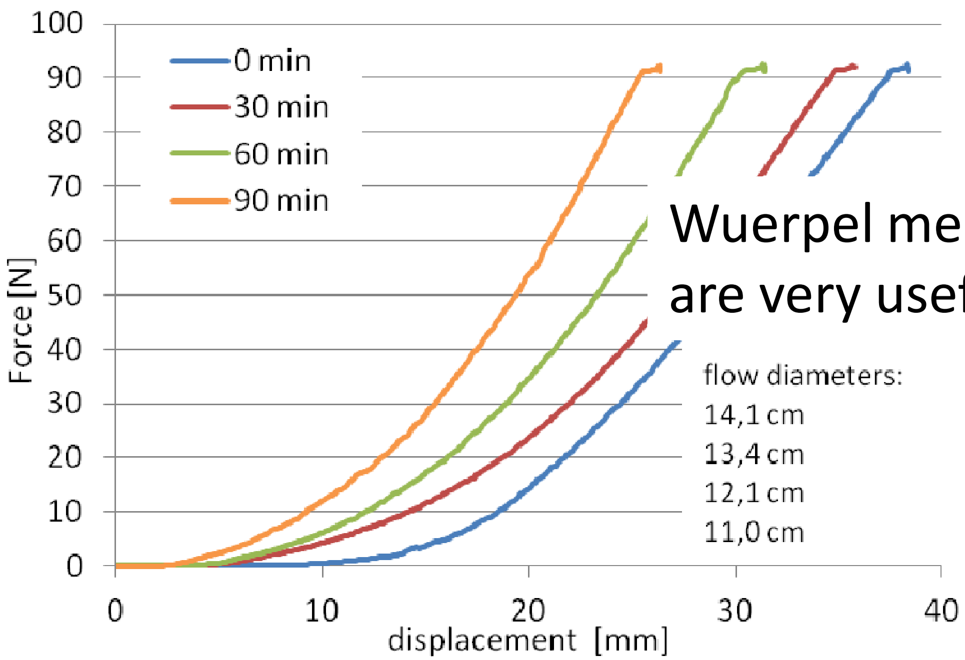
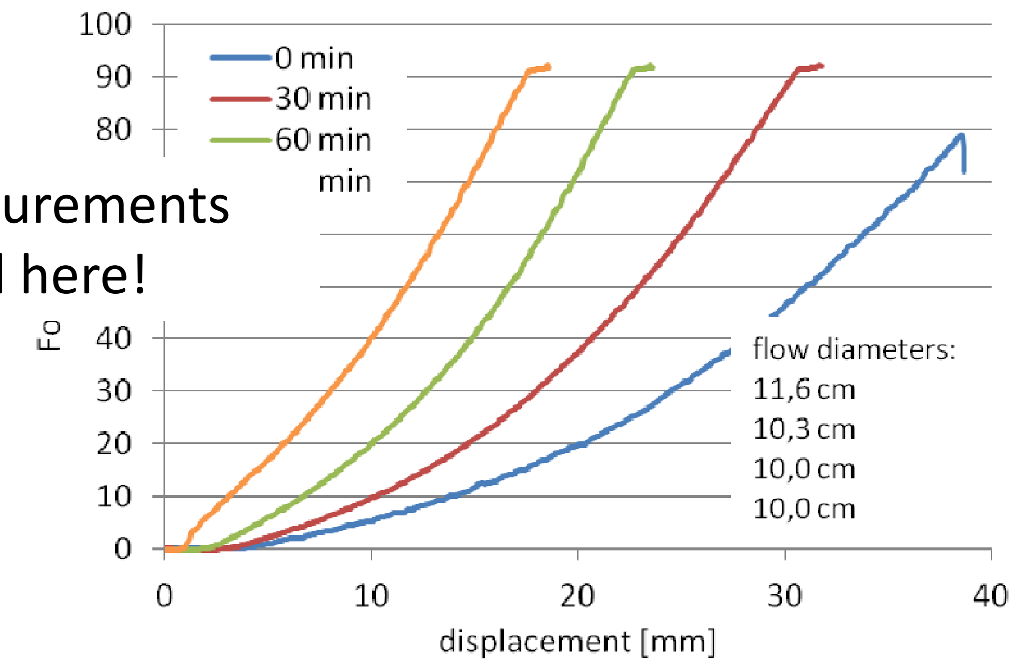
Control mixture

Mixture containing casein



Wuerpel measurements are very useful here!



Conclusions

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- The Wuerpel-Device is appropriate for mortars with high yield stress and low viscosity.
- It is inappropriate for flowable or almost flowable mortars.
- The Wuerpel-Device does not measure physical values but rather the practical performance.
- Wurpel measurements are a useful and easy to accomplish supplement to the measurement of the flow diameter.
- The measurements give valuable additional information, especially in cases where the flow diameter does not change.

Rheologische Eigenschaften von Instandsetzungsmörteln und Steinersatzmassen – Messungen mit dem Würpelgerät

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Rheological Properties of Repair Mortars – Measurements with the Wuerpel-Device

Thank you for your attention!

P. Ramge, H.-C. Kühne