EFFECT OF DYNAMIC LOADING ON COMPRESSIONAL BEHAVIOR OF DAMPING CONCRETE

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Looking to the future PATRAM 2010

outline

- damping concrete
- • research project ENREA
- • • test program
- • • • test results
- • • • • numerical studies
- • • • • • summary

material properties & applications

concrete mixture using expanded polystyrene balls as filler

density ~800 kg/m³

(standard concrete ~ 2400kg/m³)

compressive strength ~ 6N/mm²

used as foundation in reception hall of German interim storage facilities (e.g. Lingen)

two layers damping concrete plates (2*h=50cm) + steel-fibre-screed

characteristic values

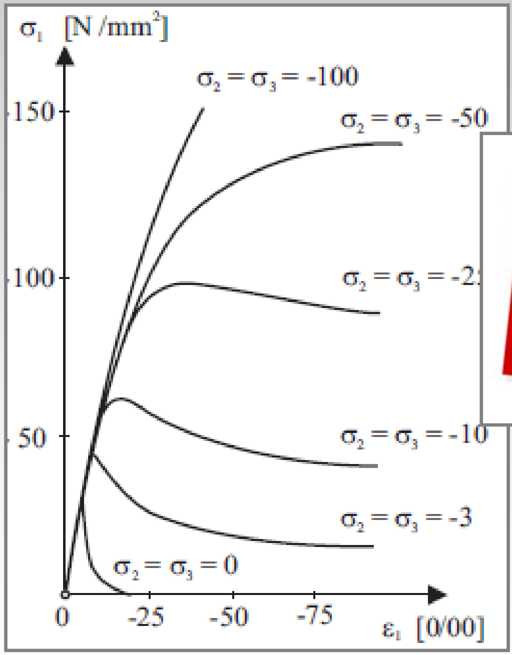
standard material properties from producer HOCHTIEF

exemplary drop tests (licensing pilot conditiong facility Gorleben, Germany)

data from generalized impact test (drop height 3.3 m, drop weight 212kg)

- penetration depth

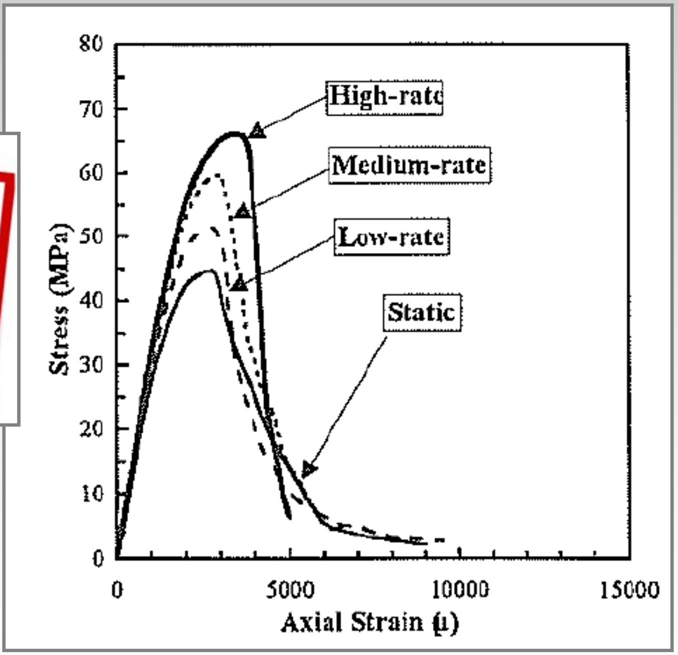
multiaxial stress –strain relations



Jamet, P. et, al., Triaxial behavior of microconcrete, Proceedings of RILEM-CEB, Touluse 1984

+ applicable numerical (material) models

strain rate dependent yield curves



Uebayashi,K. et al., Strain Softening Behaviprs of Concrete Materials under Compressive Loadings, Proceedings of SMIRT, Seoul 1999

damping concrete

objectives ENREA*

development of numerical methods for analyzing impact limiters subjected to impact or drop scenarios

* funded by the German Ministery of Education and Research
cooperation with project QUEST from WTI/GNS

- improving the reliabilty of safety assessments
- optimize dimensions and material selections for impact limiters

experimental investigations

wood (spruce)
polyurethane foam (FR3718/3730)
damping concrete

parameters:

dimensions
temperature
loading course and rate
specimen orientation
support conditions

numerical simulations

selection of appropriate material models

precalculations / sensitivity analysis

selection / development of methods for parameter identification

simulations of experiments

enhancements / implementation of appropriate material models

project stages

stage 1

servo hydraulic testing facility

cube specimen

displacement-driven compression tests

constant deformation rates [0.02 – 3000mm/s]

technical strain up to 70%

∑ 556 experiments

stage 2

drop test facility

cube specimens

impact tests with different compression rates

falling weight:

- cross section corresponding to specimen
- different drop heights / weights

∑ 486 experiment

stage 3

drop test facility

component tests

falling weights with different shapes for penetrations tests

15 experiments

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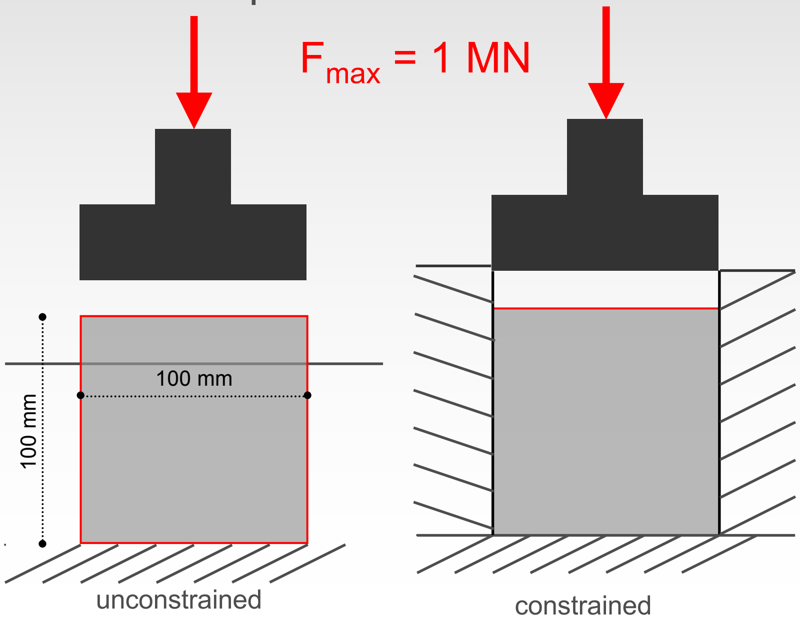
test series

first project stage (displacement-driven experiments)			
	D1= 0.02mm/s	D2= 200mm/s	D3= 3000mm/s
unconstrained	U_D1	--	U_D3
constrained	R_D1	R_D2	R_D3

- test series: 1 preliminary + 5 regular tests
- nominal technical strain 70% (max)
- additional quasi-static test to determine scale effect



second / third project stage

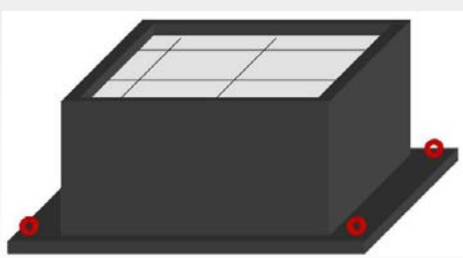
cubes 0.1x0.1x0.1m³

concrete plates: 1x1x0.5m³

drop tests

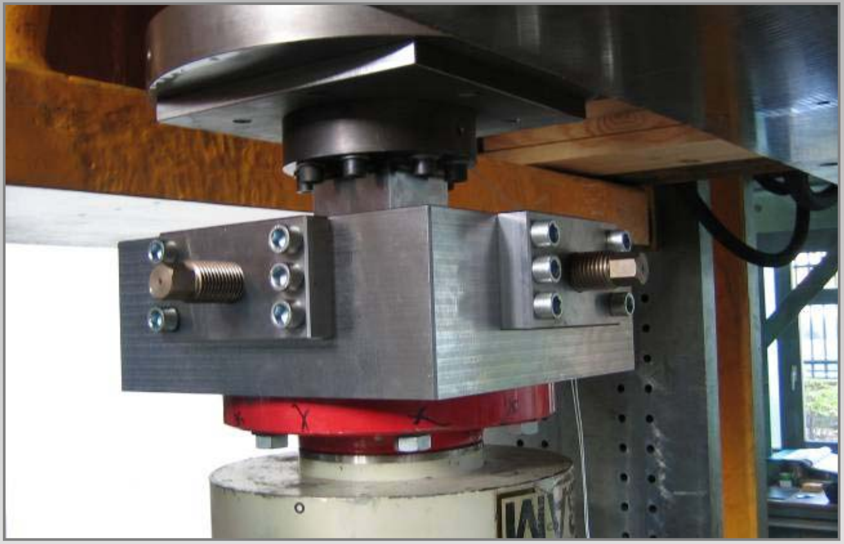
different drop weights

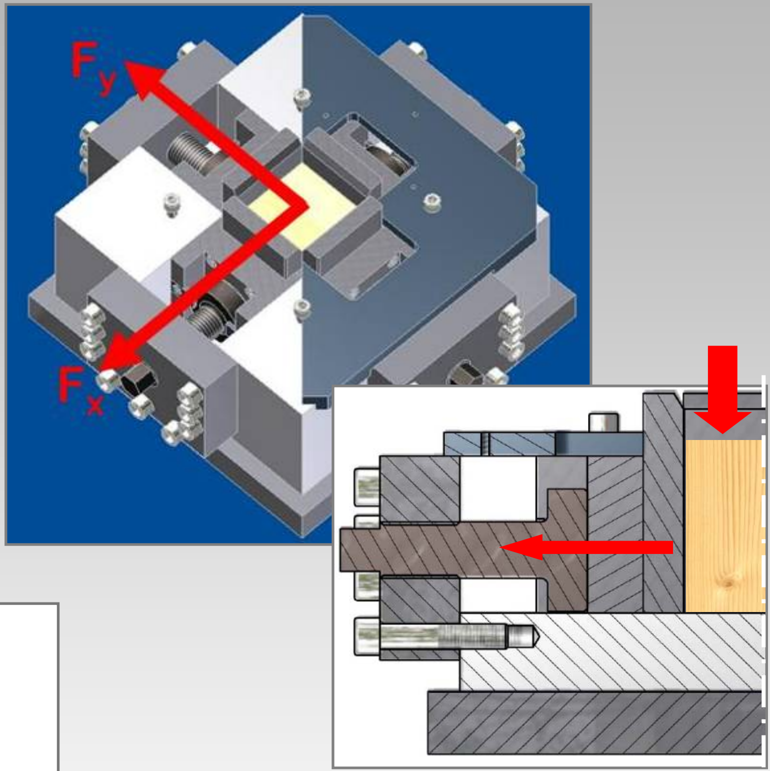
different drop shapes



experimental set up

holding jig (10x10x10 cm³)





measuring system

displacement: triangulation based sensor

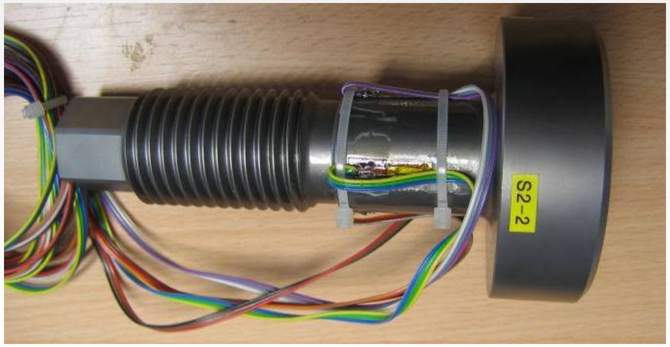
load parallel to stamp direction:

- straing gauge instrumented pressure stamp
- load cell

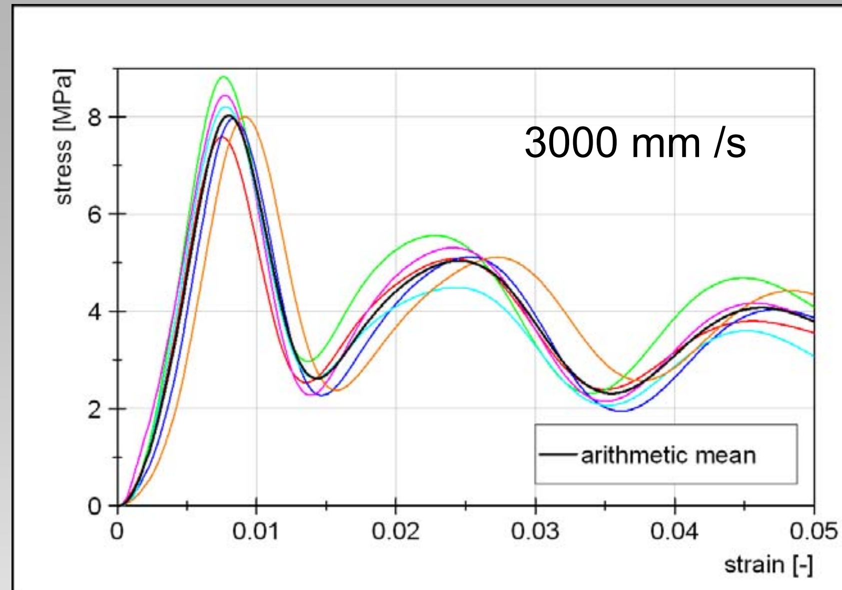
load transversal:

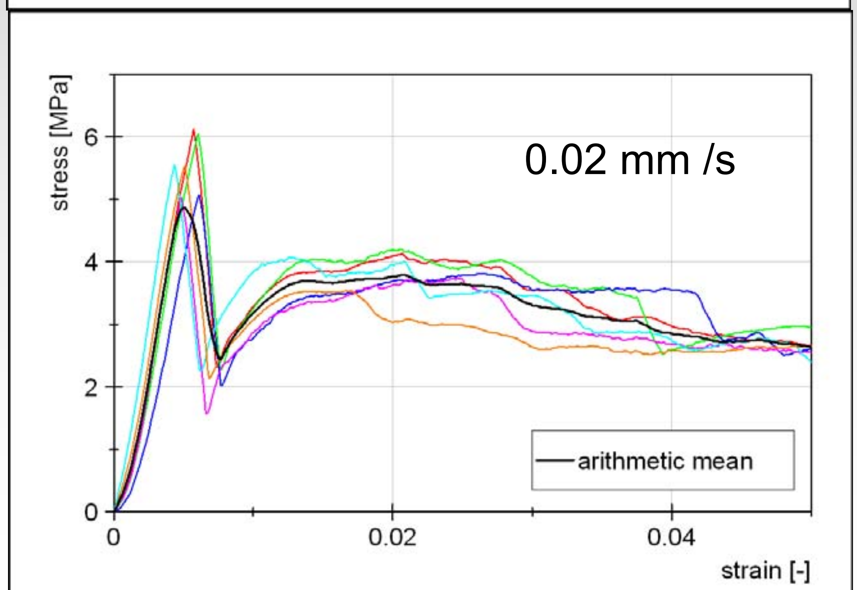
- bolts equipped with cylindrical strain gauge

temperature measurements during loading



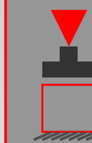
unconstrained tests



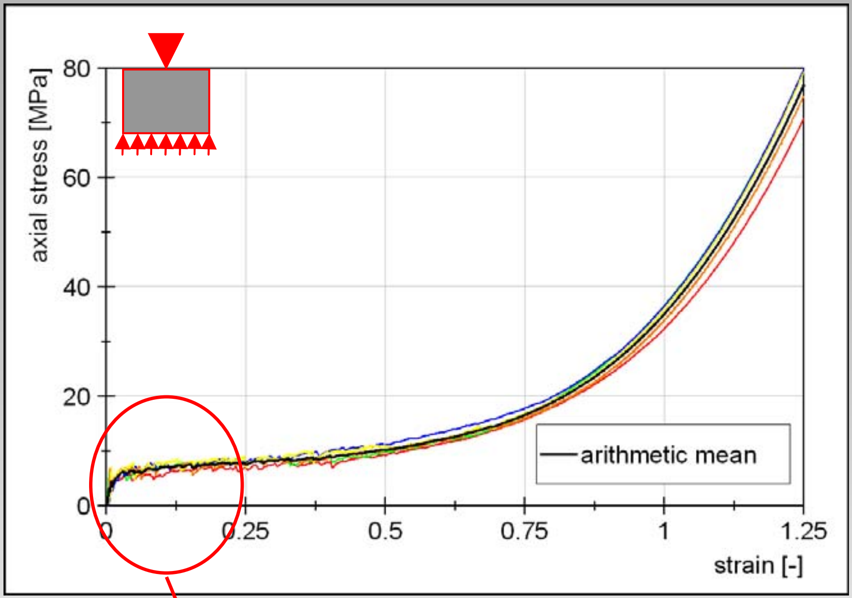


- elastic range up to 1% strain
- softening after elastic peak
- failure at approx. 1.5%
- strain rate dependent

test results



constrained tests – 0.02 mm/s

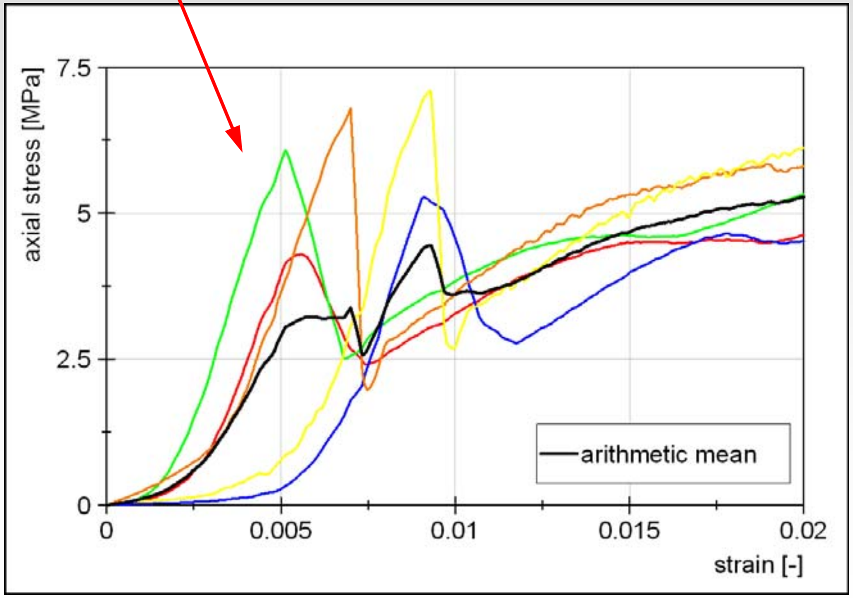


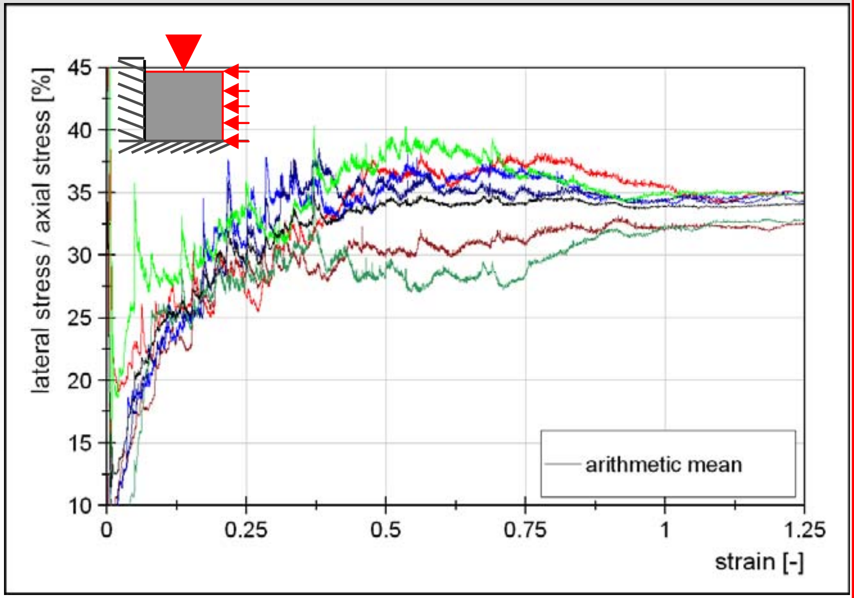
four zone stress-strain relation:

- elastic
- softening
- plateau
- densification

considerable scattering

nearly constant ratio lateral / axial stress at high strain levels





test results

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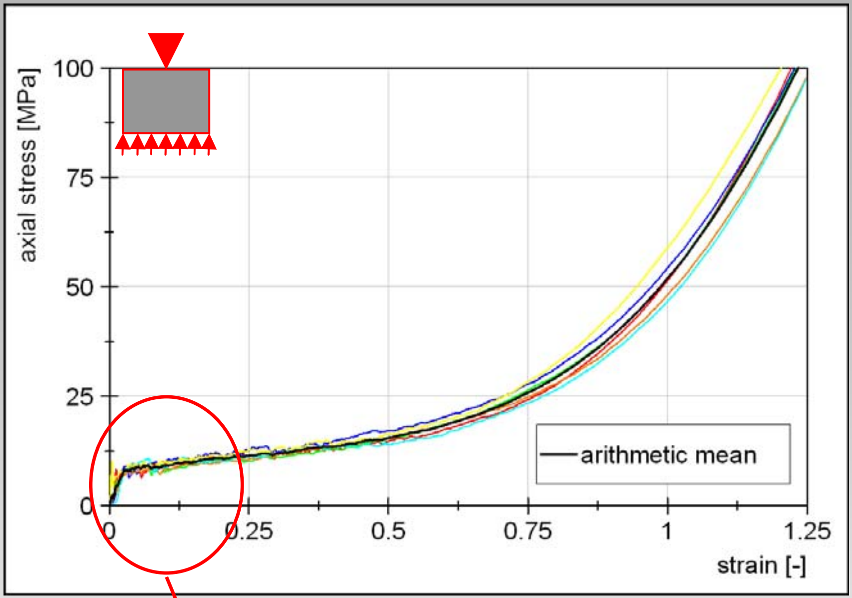
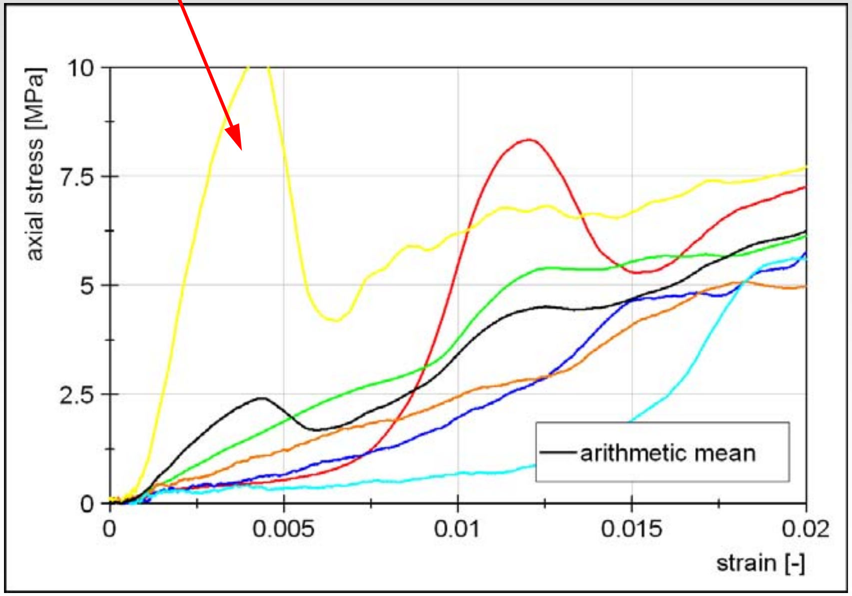
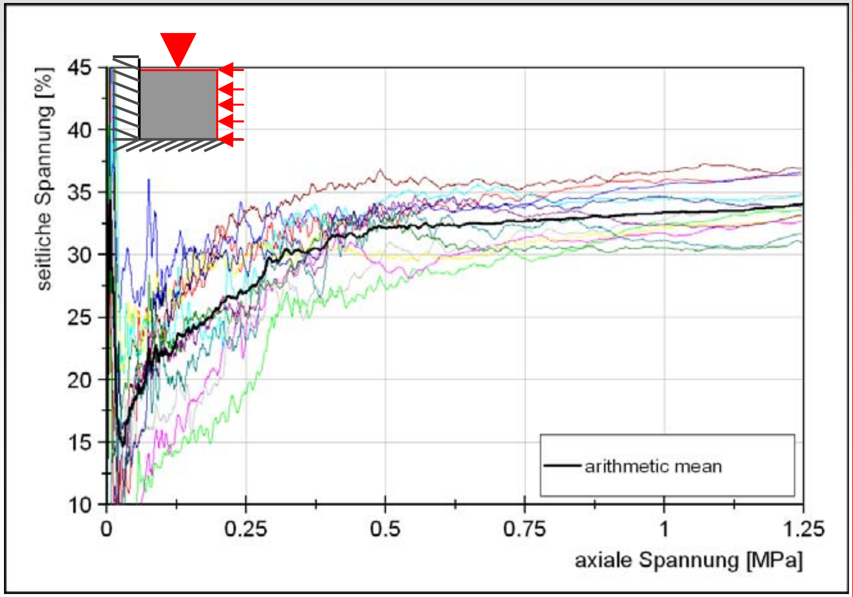
constrained tests – 3000 mm/s



- dynamic stress-strain relations similar to quasi-static response (elastic / softening / plateau / densification)
- elastic and softening zones are partly merged together
- mean ratio lateral / axial stress slightly lower , but likewise constant
- significant dynamic hardening





● ● ● ● test results

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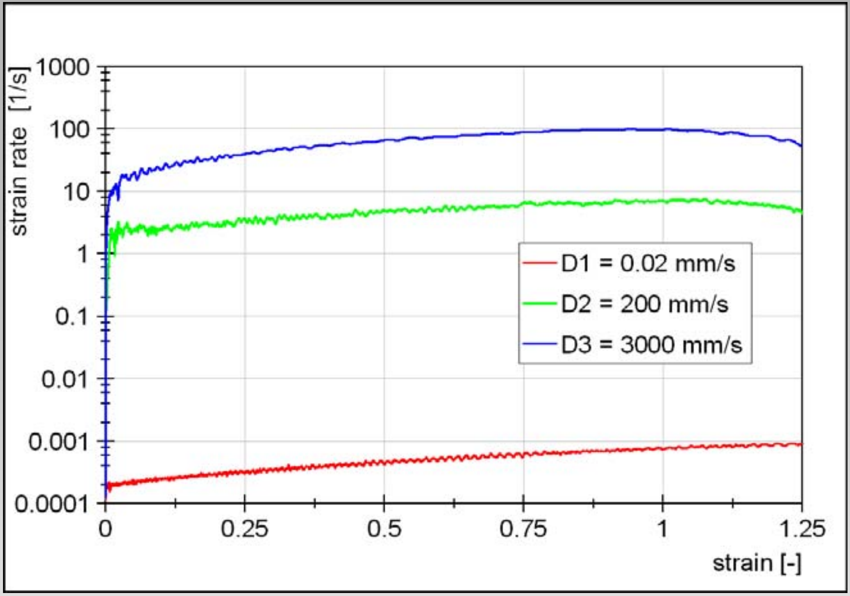
strain rate sensitivity

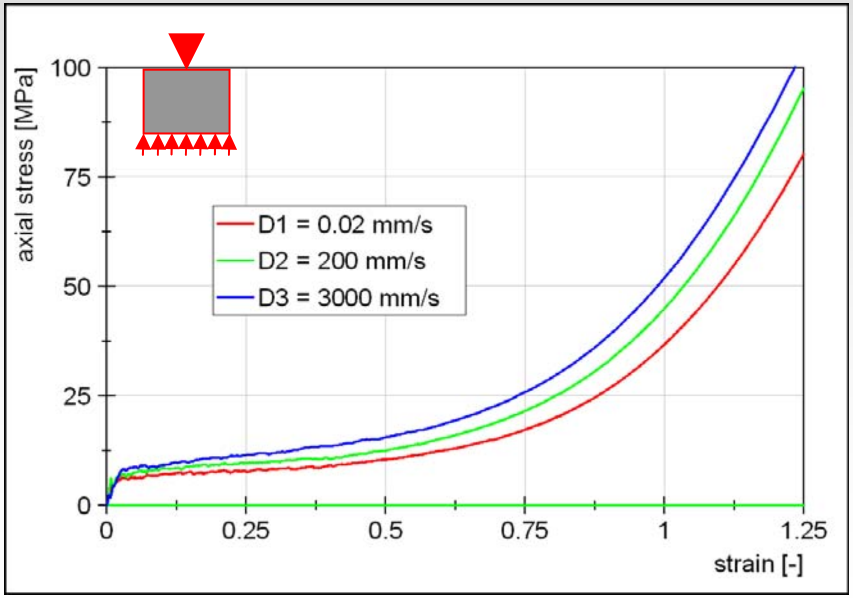


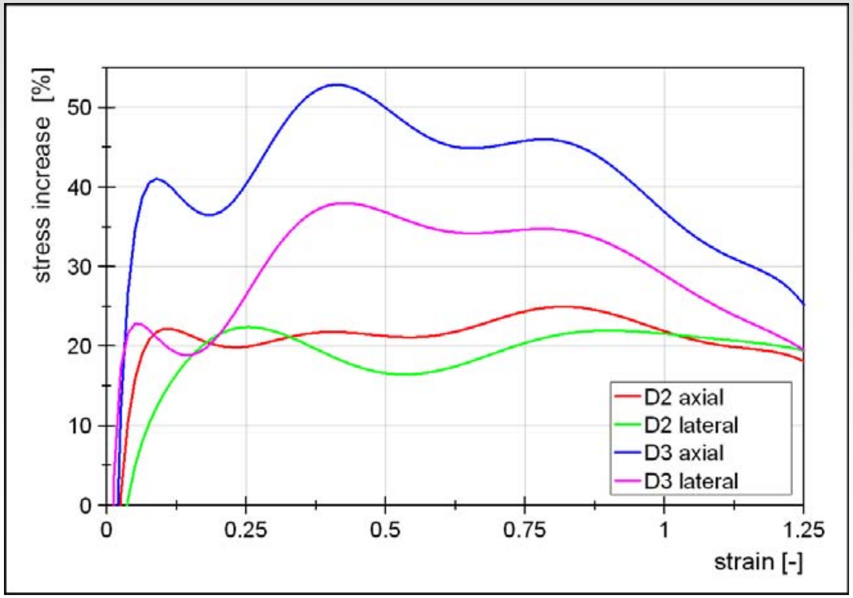
	(D1►D2)	(D2►D3)
strain rate	+ e^4	+ e^1
stress	+ ~ 20%	+ ~15%

hardening not conform to logarithmic rule

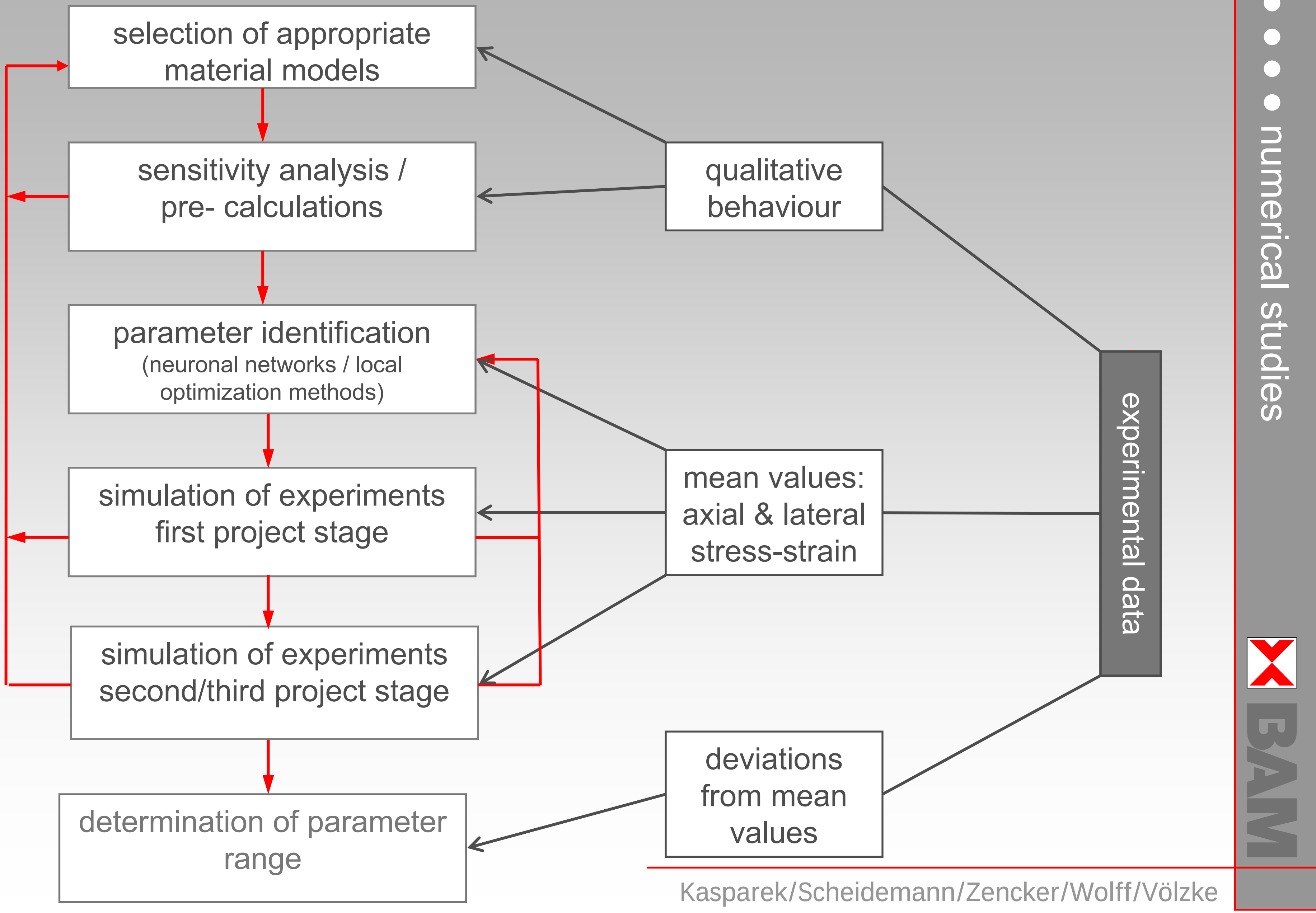
ratio dynamic / static yield stress decreases for high strain rates

dynamic effect on lateral loads less evident

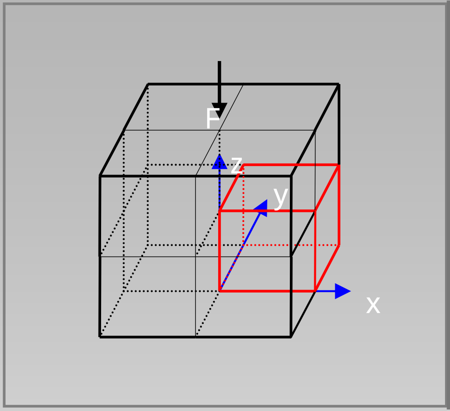


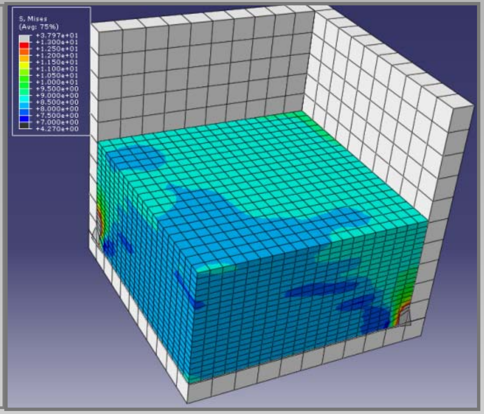


adaption of material models



FE model





solver Abaqus explicit

rigid foundation / walls

no thermal coupling

8-node solid elements

reduced integration

validated by simulating experiments with reference materials

studies on mesh size / friction coefficients

isotropic plasticity models
(Abaqus library)

crushable foam

nonassociated plasticity model for cellular materials based on monotonic yield curve

Deshpande / Fleck
Isotropic constitutive models for metallic foams, J.Mech.Phys.Solids 1989

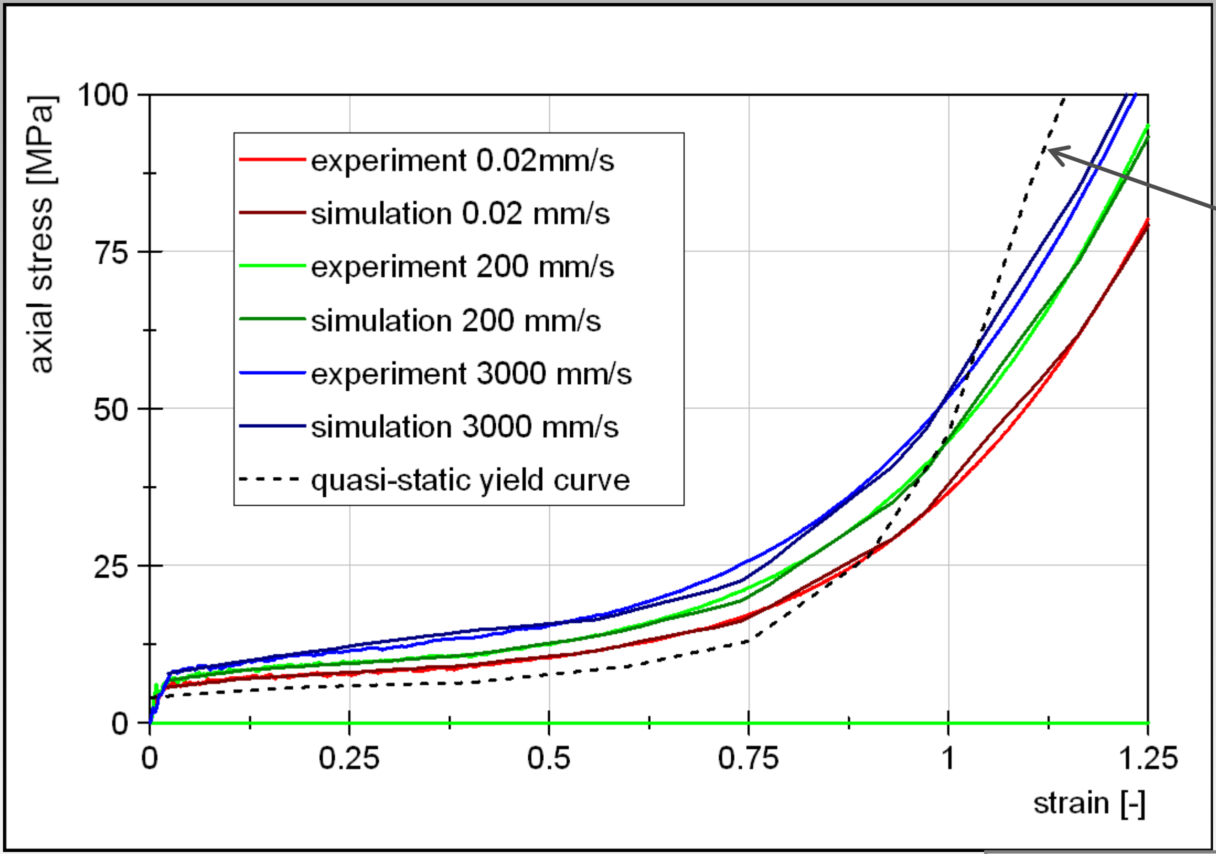
concrete damaged plasticity

combination of nonassociated tensile and compressive plasticity and damaged elasticity

Lubliner et al.
A plastic damage model for concrete
Int J. Solids Struct. 1989

➢ failed in reproducing densification at high strains

results



seven – node- yield curve

scaling factor to capture dynamic hardening

good approximation of constrained experiments at different deformation speeds

no provisions to reproduce damage / softening behaviour

numerical studies

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summary

constrained and unconstrained displacement-driven test series with different deformation rates completed

identification of a 4-zone stress-strain relation and significant dynamic hardening

evaluation of applicable numerical material models

simulations based on *crushable foam* yield good agreement with experimental results

further work needed to sucessfully simulate softening behavior

thank you

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