Projektkonferens InfraSweden2030

DIGIROAD

– Simulation of handling, transport and compaction of unbound aggregates in road construction

Johannes Quist (PhD), Projektledare

Klas Jareteg, (PhD)

Med stöd från:

VINNOVA

Energimyndigheten

FORMAS

STRATEGISKA INNOVATIONS-PROGRAM

INFRA SWEDEN 2030

FRAUNHOFER CHALMERS
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Projektets syfte

Projektmål:

”Simulera bergmaterial och dess interaktion med maskiner från bergtäkt till kompakterad vägkropp för att öka kvalité, bärighet och livslängd.”

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Simulation of handling and compaction of unbound aggregates in road construction

Problem:
Road quality and life expectancy influenced by process variance in handling and compaction of UGMs

Hypothesis:
High resolution digitalization of rock materials and construction equipment will enable a step-change in problem solving and research capabilities.

Proposed solution:
World class DEM solver for unbound rock aggregates

- Industrial scale validation through case studies
- Material model calibration via laboratory experiments
- High-performance computing

Process steps:


Blasting


Crushing


Stockpile


Loading


Transport


Unloading


Spreading

Compaction

Consortium:

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NCC

CHALMERS
UNIVERSITY OF TECHNOLOGY

VOLVO
Volvo Construction Equipment

DYNAPAC
FAYAT GROUP

Details:

Project Leader
Johannes Quist

Coordinating part
Fraunhofer-Chalmers Centre

Duration
2018-05-01 to 2021-03-31

Budget
8 800 000 (50% in-kind)

People involved

NCC

Kristoffer Hofling
NCC

Pär Johnning
NCC

Per Murén
NCC

Bo Johansson
NCC

Christina Claeson-Jonsson
R&D chef, NCC

Volvo Construction Equipment

Martyn Luby
Volvo CE

Andreas Hjertström
Volvo CE

Dynapac

Andreas
Persson
Dynapac

Fredrik Åkesson
Dynapac

Chalmers University of Technology

Magnus Evertsson
Professor

Hanna Quist
Contracted student

Fraunhofer-Chalmers Centre

Johannes Quist
Project Leader

Franziska Hunger
Applied researcher

Elin Solberg
Applied researcher

Klas Jareteg
Lead code developer

Adam Bilock
Applied researcher

Fredrik Edelvik
Head of Department

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DIGIROAD | Work Package Chart

WP1. Project Coordination — WPL: Johannes Quist

WP6. Road life probability modelling — WPL: Magnus Evertsson

Aggregate Compaction

SIM

WP2. Compaction Modelling (Sim)

WPL: Elin Solberg

EXP

WP3. Compaction Experiments (Lab)

WPL: Magnus Evertsson

Validation

Road Construction Process

SIM

WP4. Process Modelling

WPL: Klas Jareteg

EXP

WP5. Field Experiments

WPL: Johannes Quist

Validation

Sample Material
- NCC

Process Knowledge
- NCC
- VCE
- Dynapac

Test Site
- NCC
- VCE

Machine Equipment
- NCC (Cr. Plant, loaders)
- VCE (Loader, Dumper, ..)
- Dynapac (Roll. Comp)

Machine operator time
- NCC
- (VCE)
- (Dynapac)

Aggregate laboratory
- Chalmers
- NCC

Measurement equipment
- Chalmers (3D scanner)
- NCC (lab)
- Dynapac (packing, R_M)

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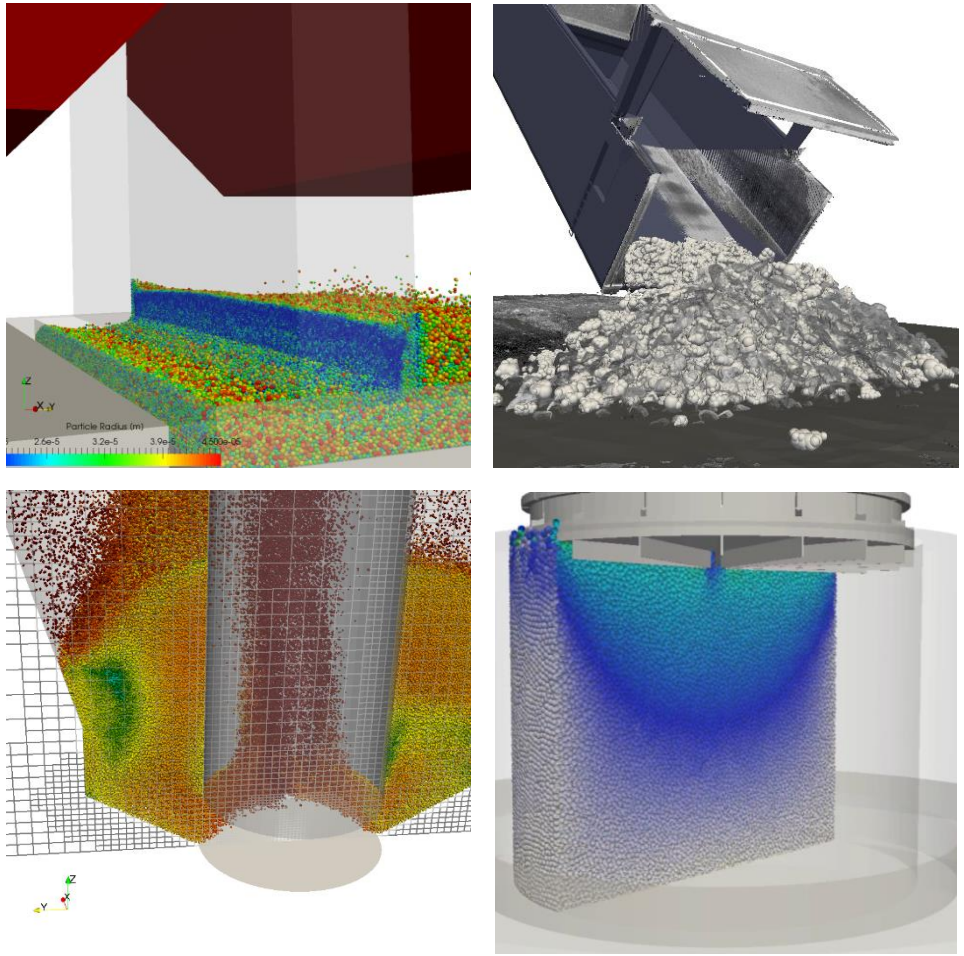
Demify® – Software status

- Discrete element method code developed at FCC since 2016
- Application areas:
  - Pharmaceutical industry
  - Infrastructure
  - Additive manufacturing
  - Mining
  - Bulk materials handling
- Fluid-particle interaction solved in collaboration with in-house solver IBOFlow®
- GUI on in-house IPS platform during 2020



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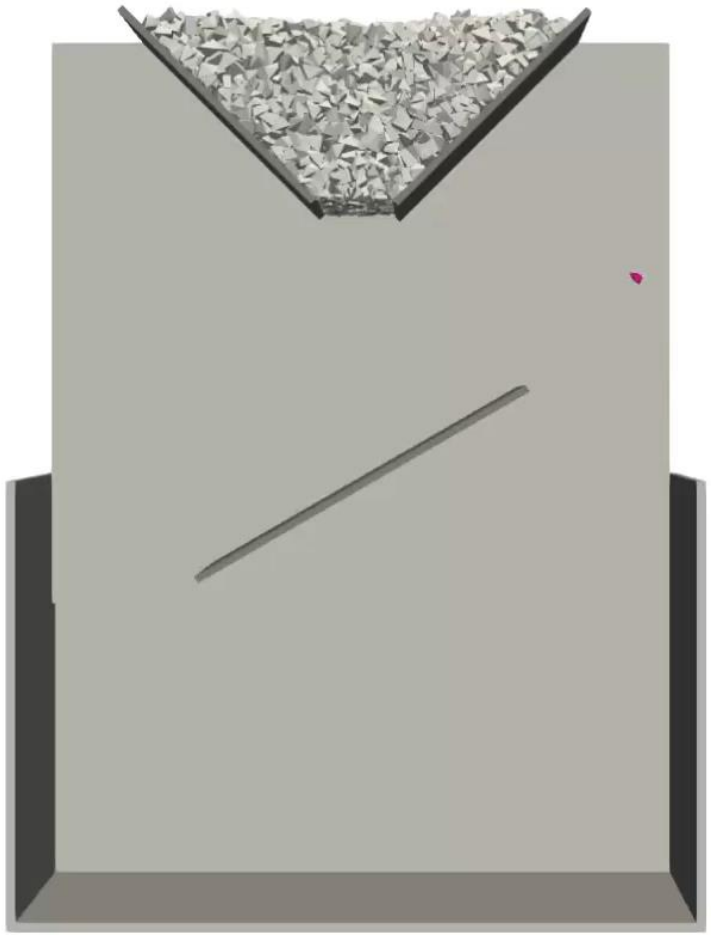
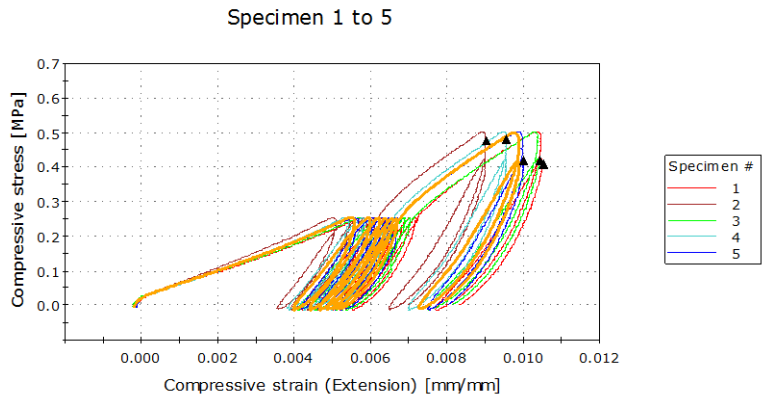
Material Model Calibration





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DIGIROAD

Simulation of handling and compaction of unbound aggregates in road construction

Case study 2018 – Full-scale flow experiments for DEM validation and examination of segregation effects

Scope:

1. Develop a data-set that can be used for industrial scale validation of DEM simulations

2. Investigate the mechanisms and effects of size segregation during unloading

Method:

- Multi-camera system
- Laser 3D scanning
- Material sampling
- Motion capture

Info:

- SBUF project support
- Project owner: NCC
- Project leader: Pär Johnning
- Test location: NCC Stenungsund
- Machinery: Volvo L180H / Volvo FMX (SLP)

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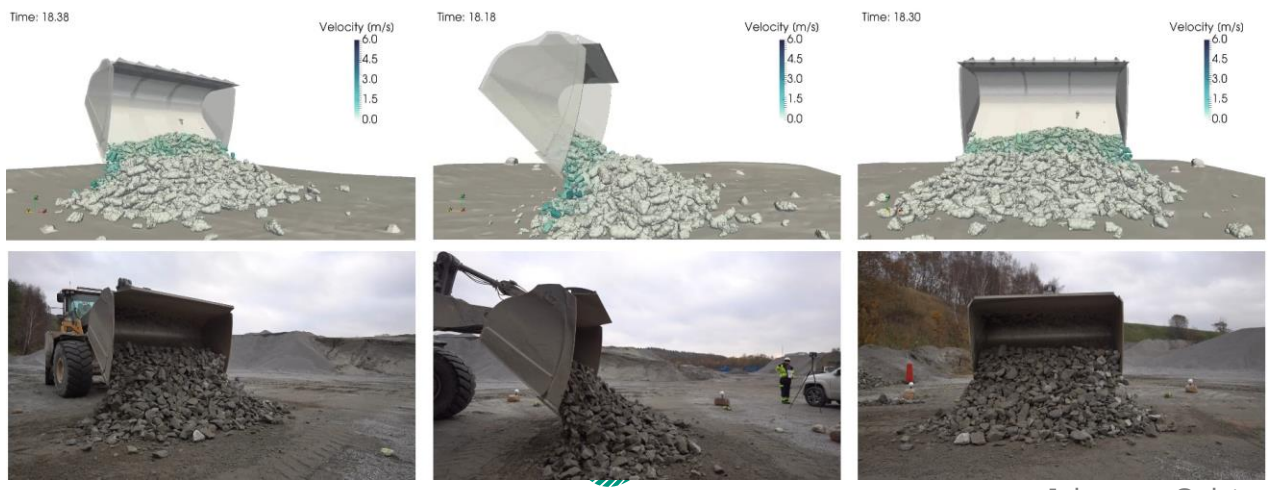
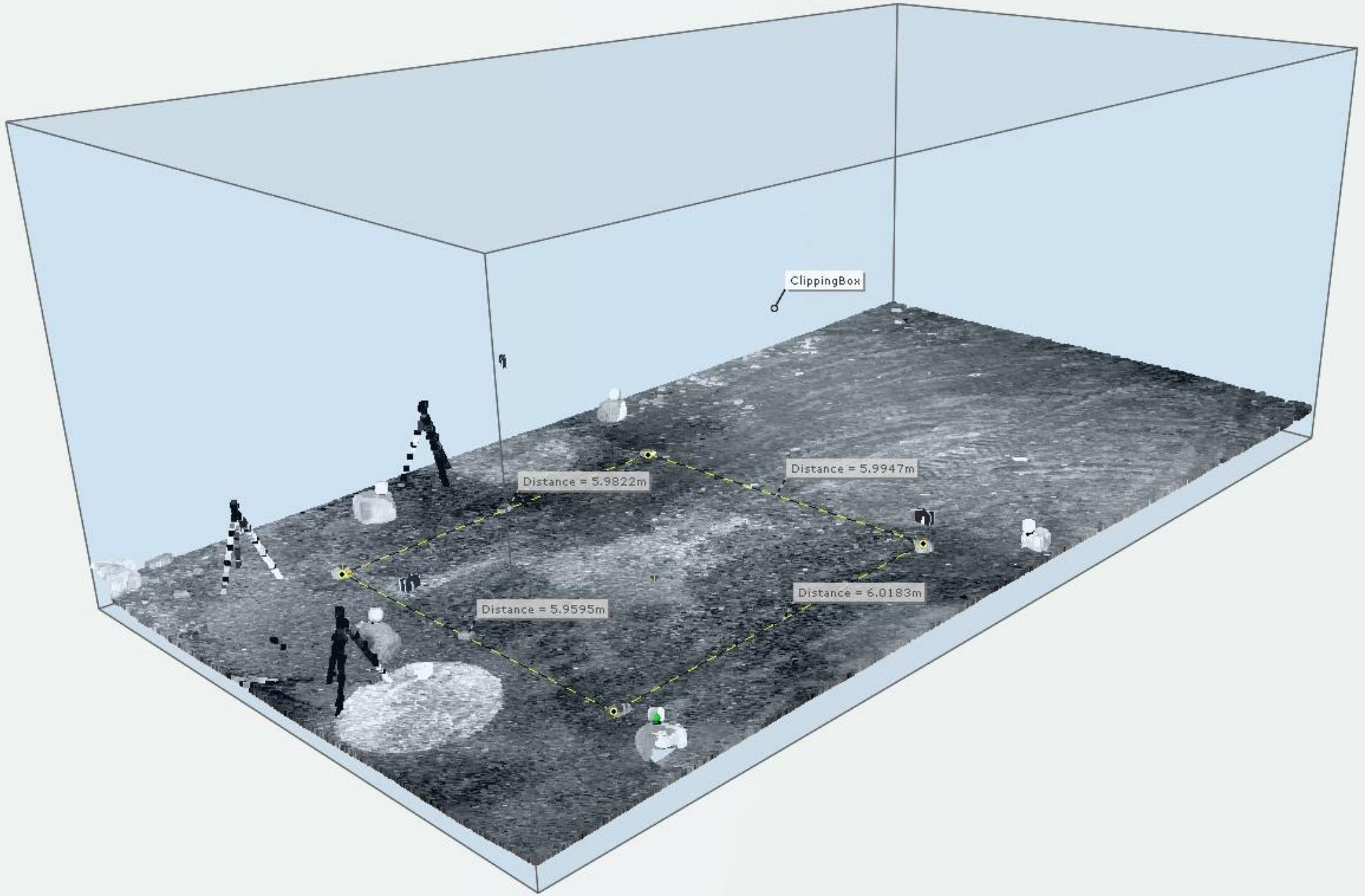
The development fund of the Swedish construction industry

Truck unloading

Wheel loader unloading

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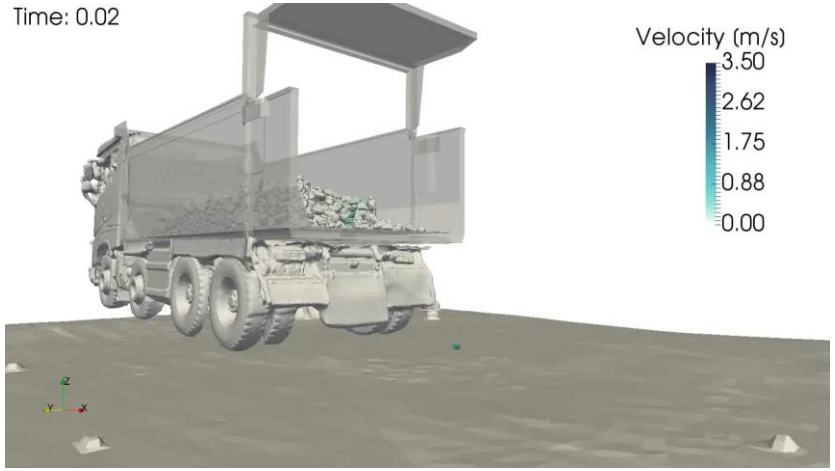
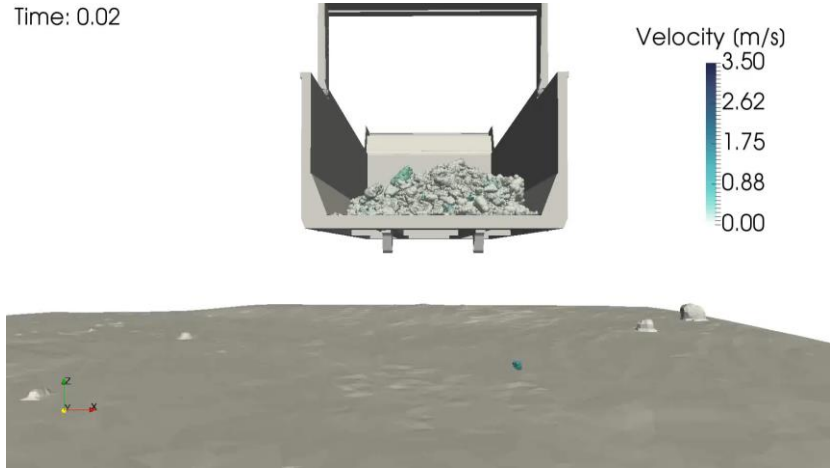
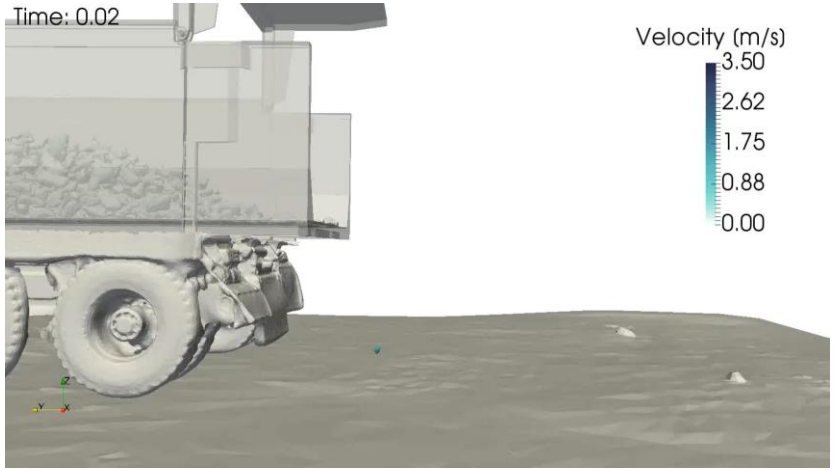
Distance = 5.9947m
Distance = 5.9595m
Distance = 6.0183m

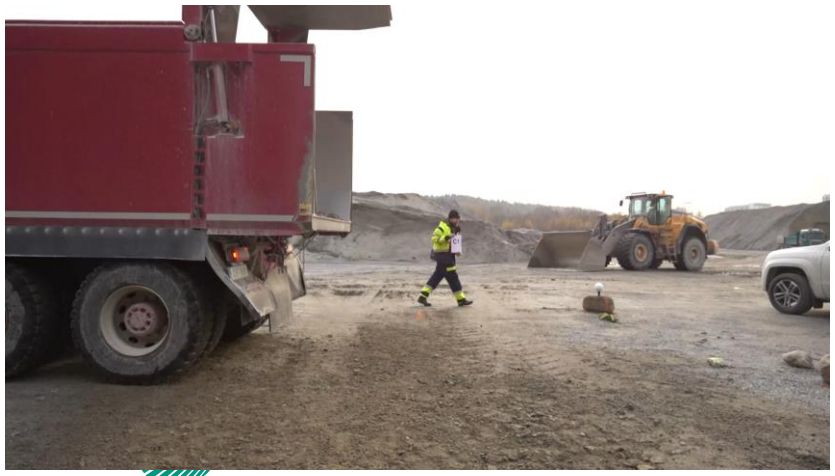
This simulation completed ID: C1_T12

C1 T12 - Comparison









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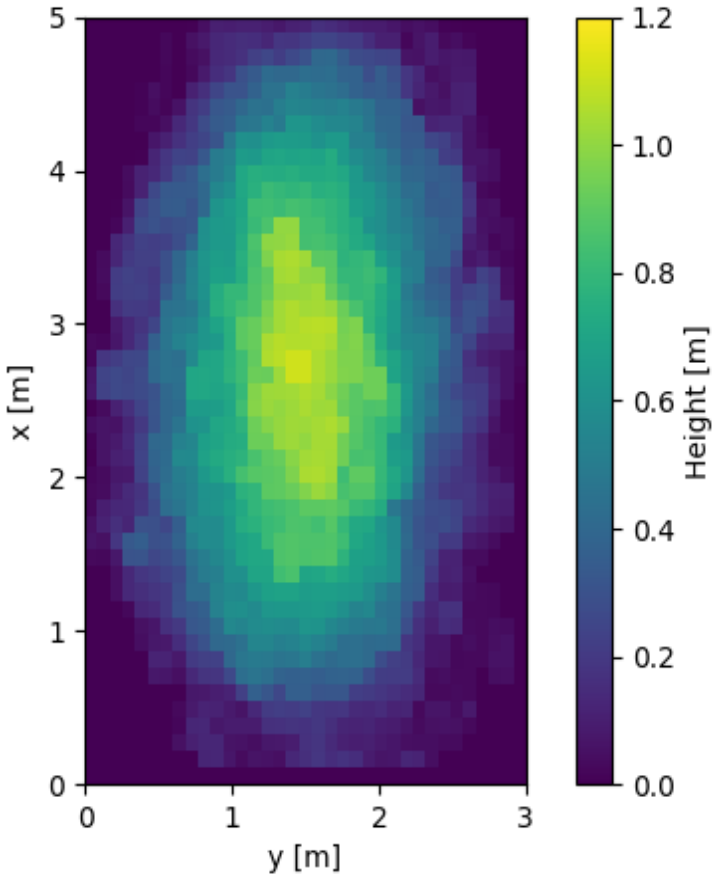
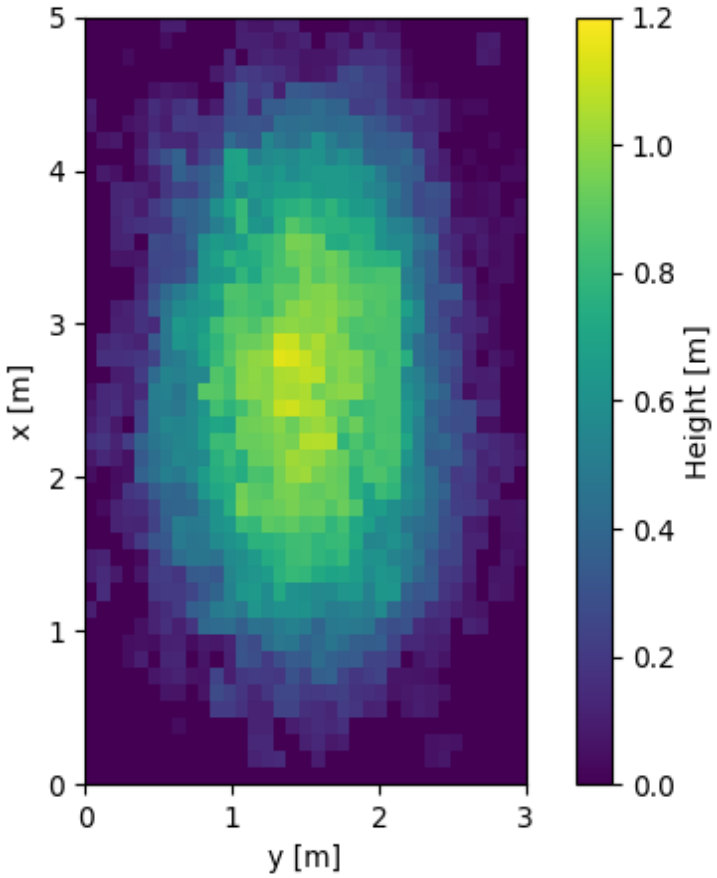
C1 comparison simulation – experiment

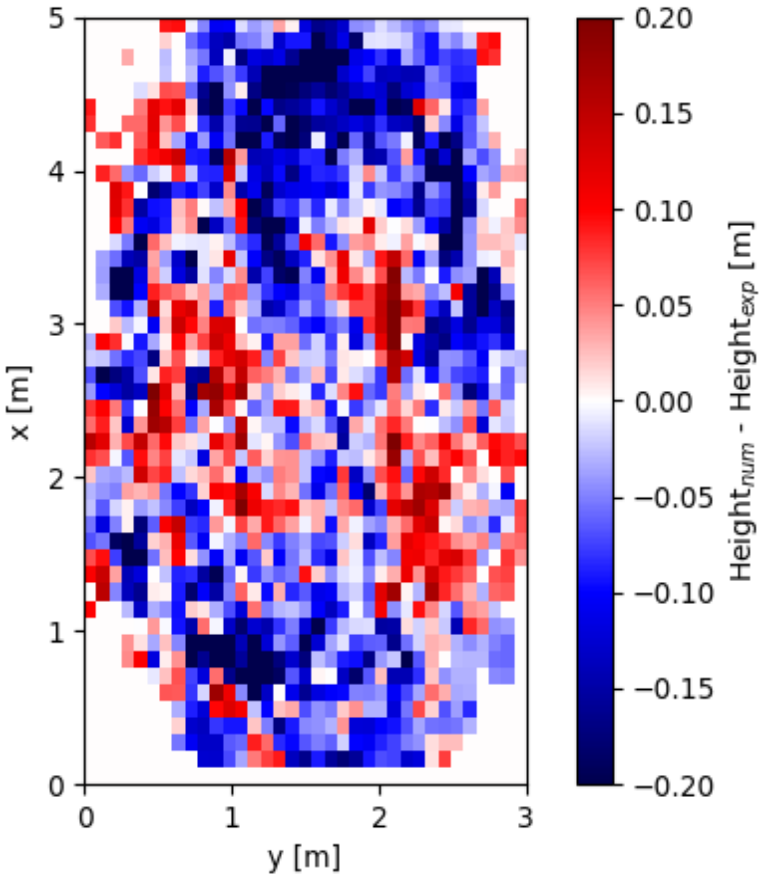
a) Experiment



b) Simulation



c) Difference



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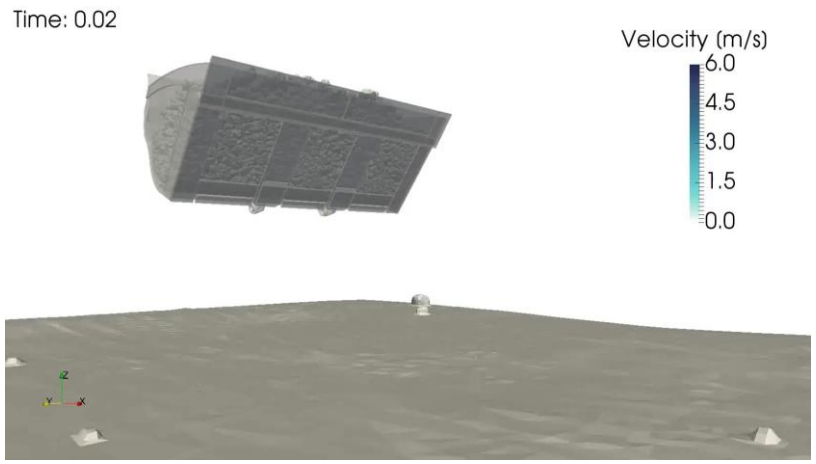
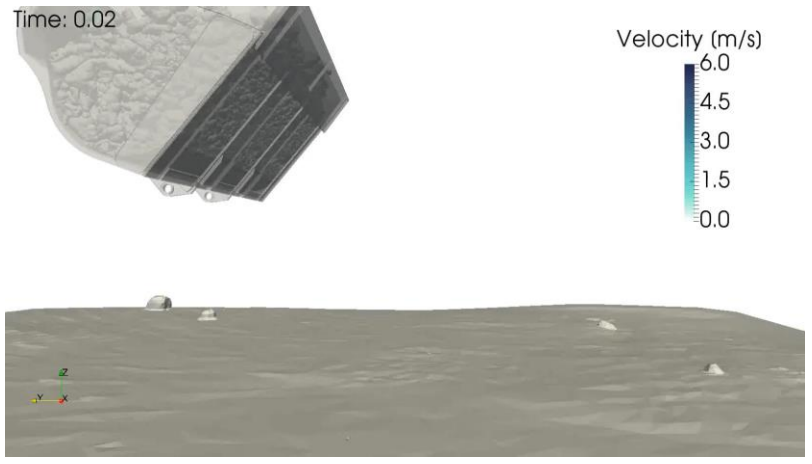
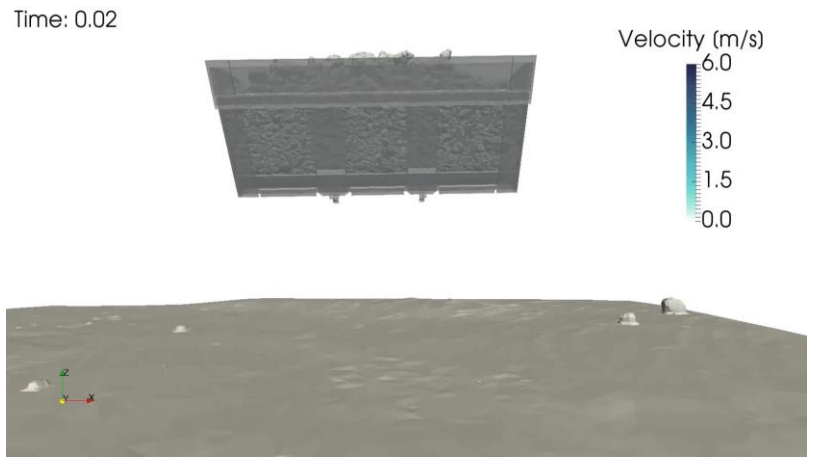
C2 Wheel Loader +22/-250

This simulation ID: C2_V5







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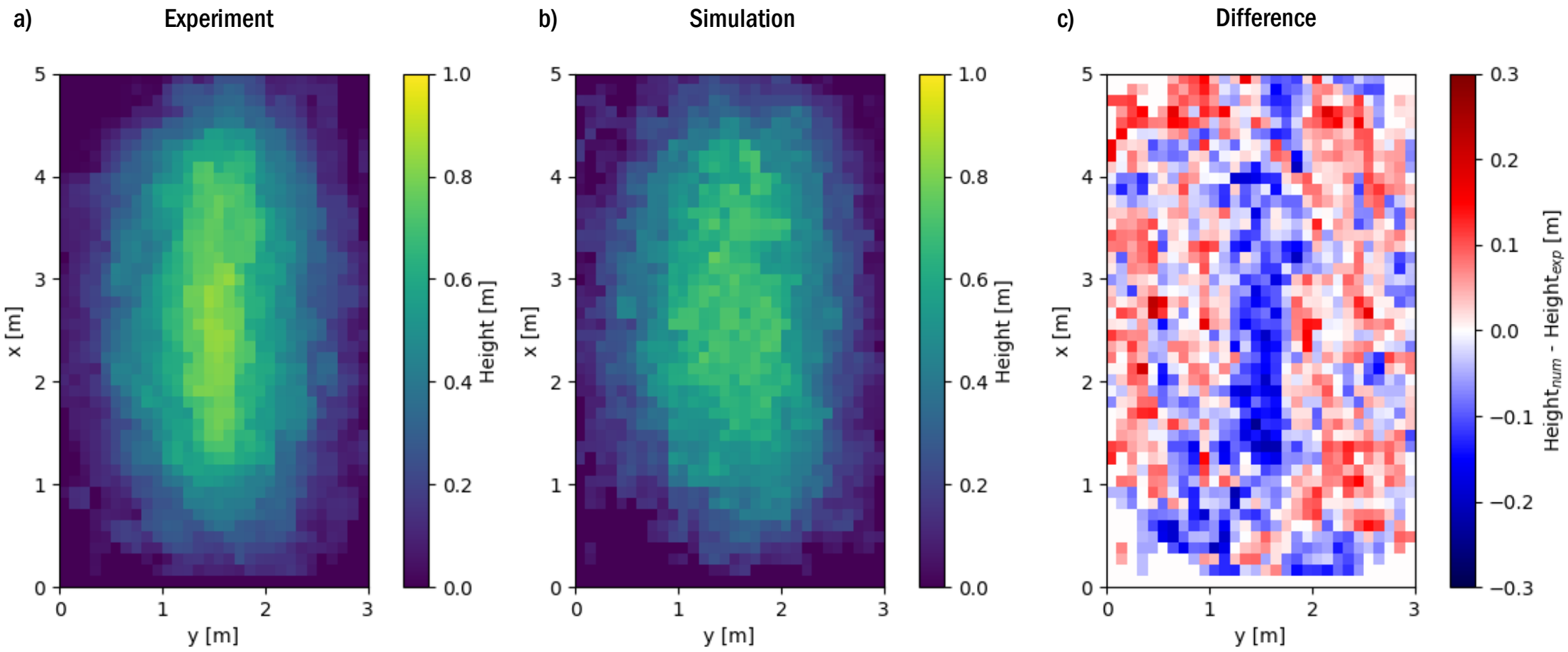
This simulation ID: C2_T5

C2 pile formation



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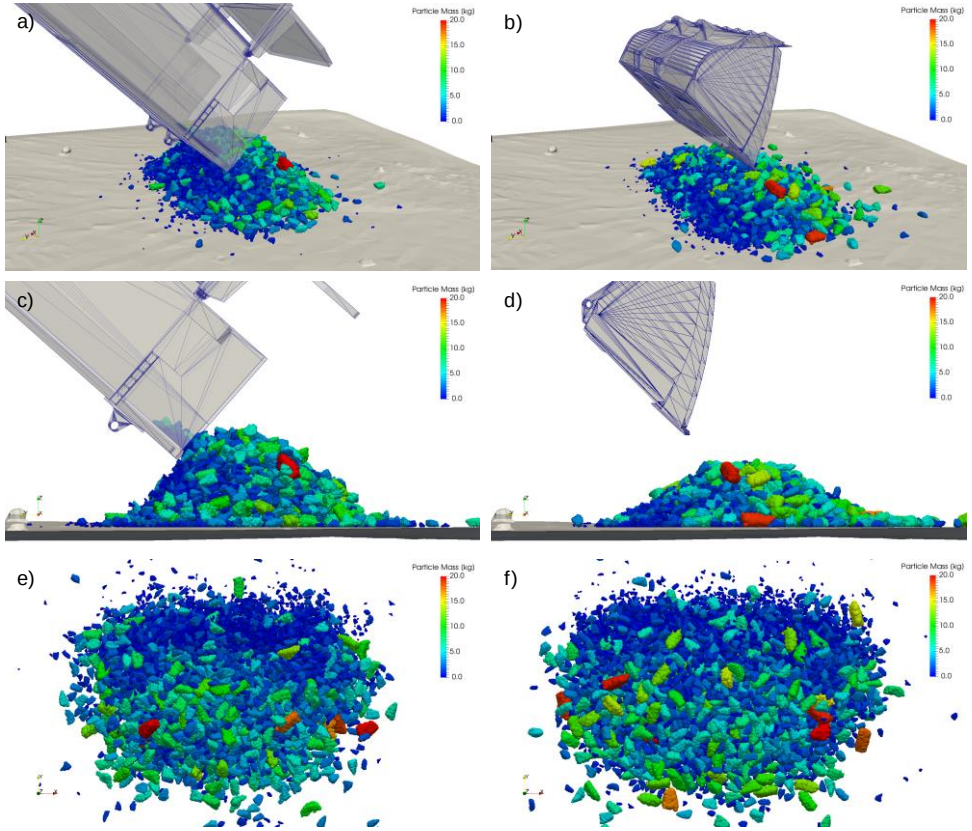
Case study 2018 – Full-scale flow experiments for DEM validation and examination of segregation effects

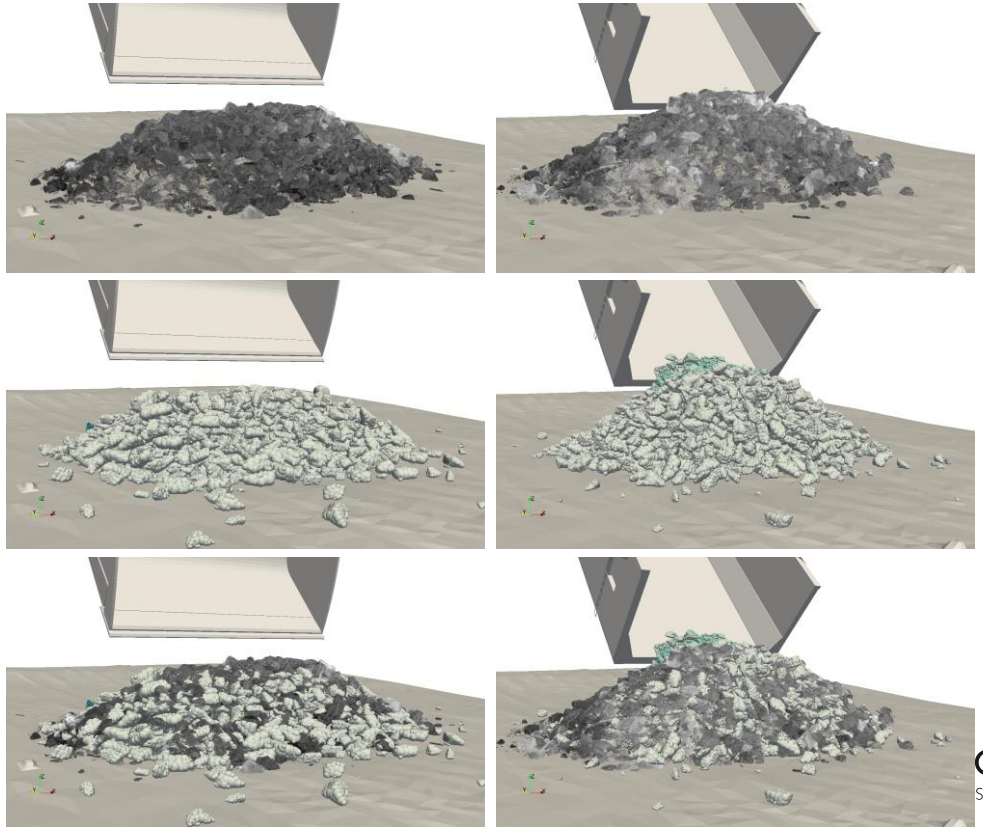
Segregation

The mechanism of size segregation strongly influences the homogeneity of the pile formation in terms of particle size distribution



Validation

The simulation results demonstrated a high level of congruence in terms of particle flow characteristics and rock pile formation topography



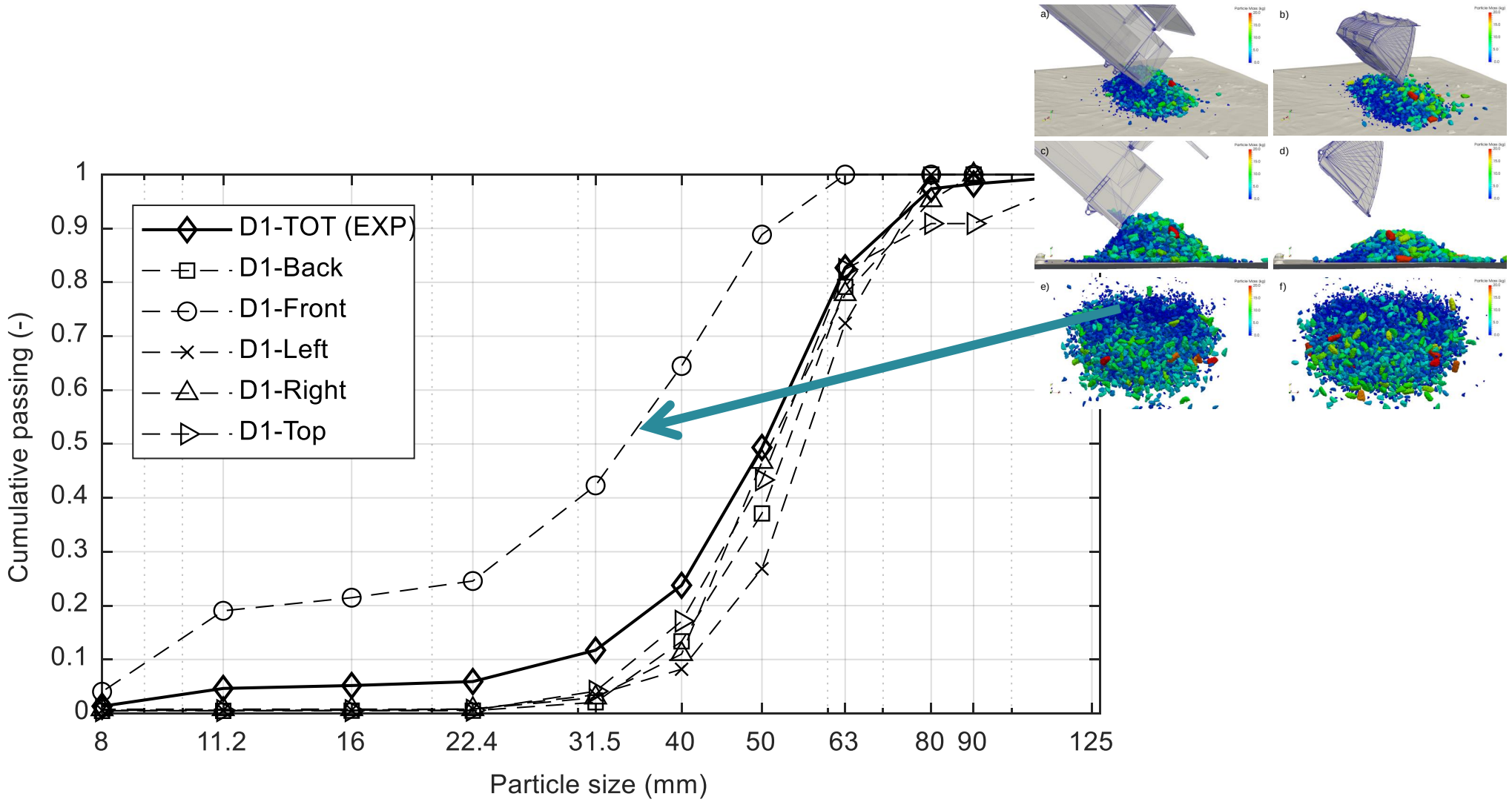


Figure 23. Particle size distribution for the D1 truck unloading test (+22/-90 & +8/-11 mm).

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Simulation of handling and compaction of unbound aggregates in road construction

Case study 2019-20 – Investigation of segregation effects and compaction of unbound materials

Scope:

1. Develop a data-set that can be used for industrial scale validation of DEM roller compaction simulations

2. Investigate the influence of different UGM size distributions on the compaction response

Method:

- Multi-camera system
- Laser 3D scanning
- Material sampling
- Ground pressure load cells
- Static load plate test & CMV
- Laser level measurements
- Material: +8/-90, +8/-32, +0/-32
- 12 compaction passes

Info:

- SBUF project support
- Project owner: NCC, Kristoffer Hofling
- Project partners: FCC, Dynapac, VTI
- Test location: Dynapac Lab Karlskrona
- Machinery: Dynapac CA3500D
- Status: Ongoing until 2020-12-15

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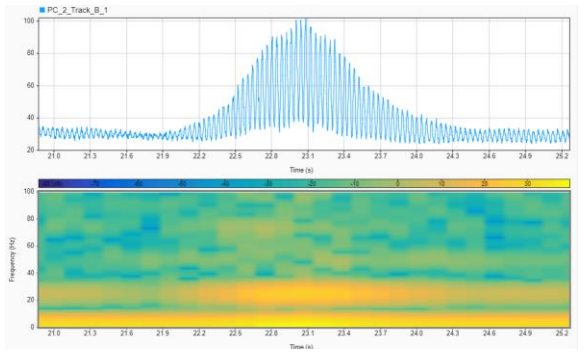

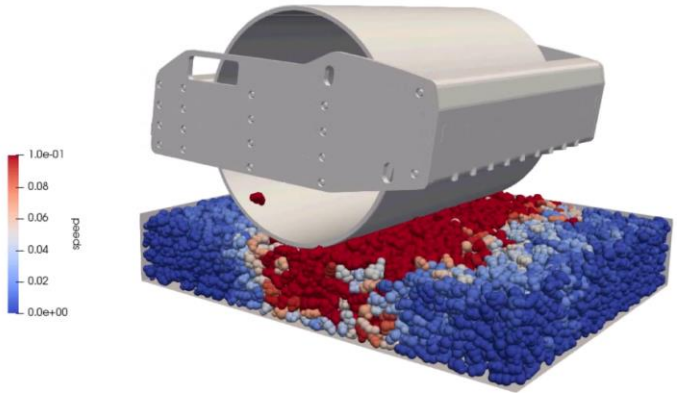

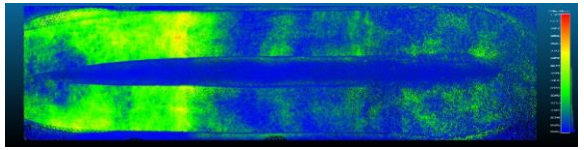

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Johannes Quist


DYNAPAC

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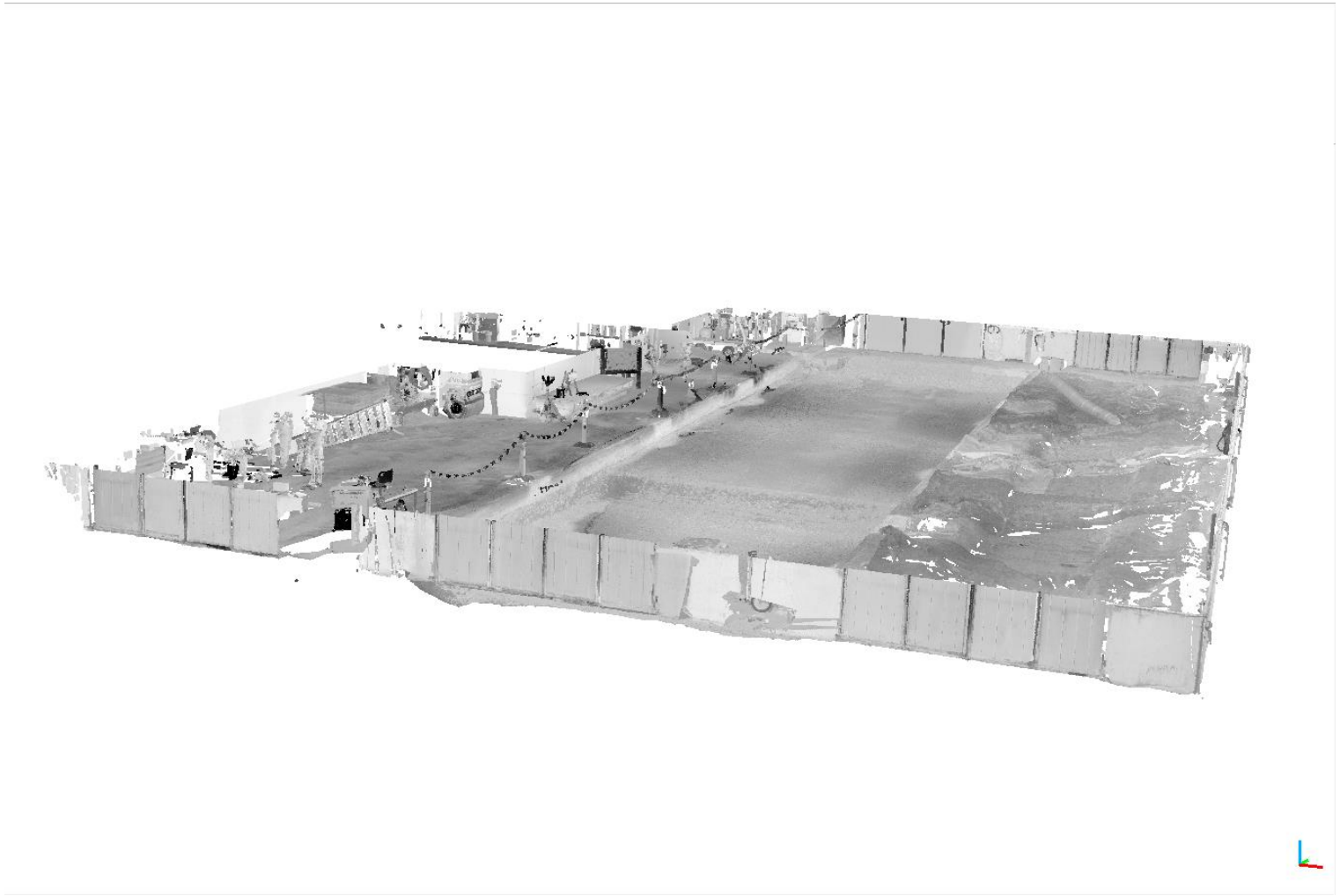

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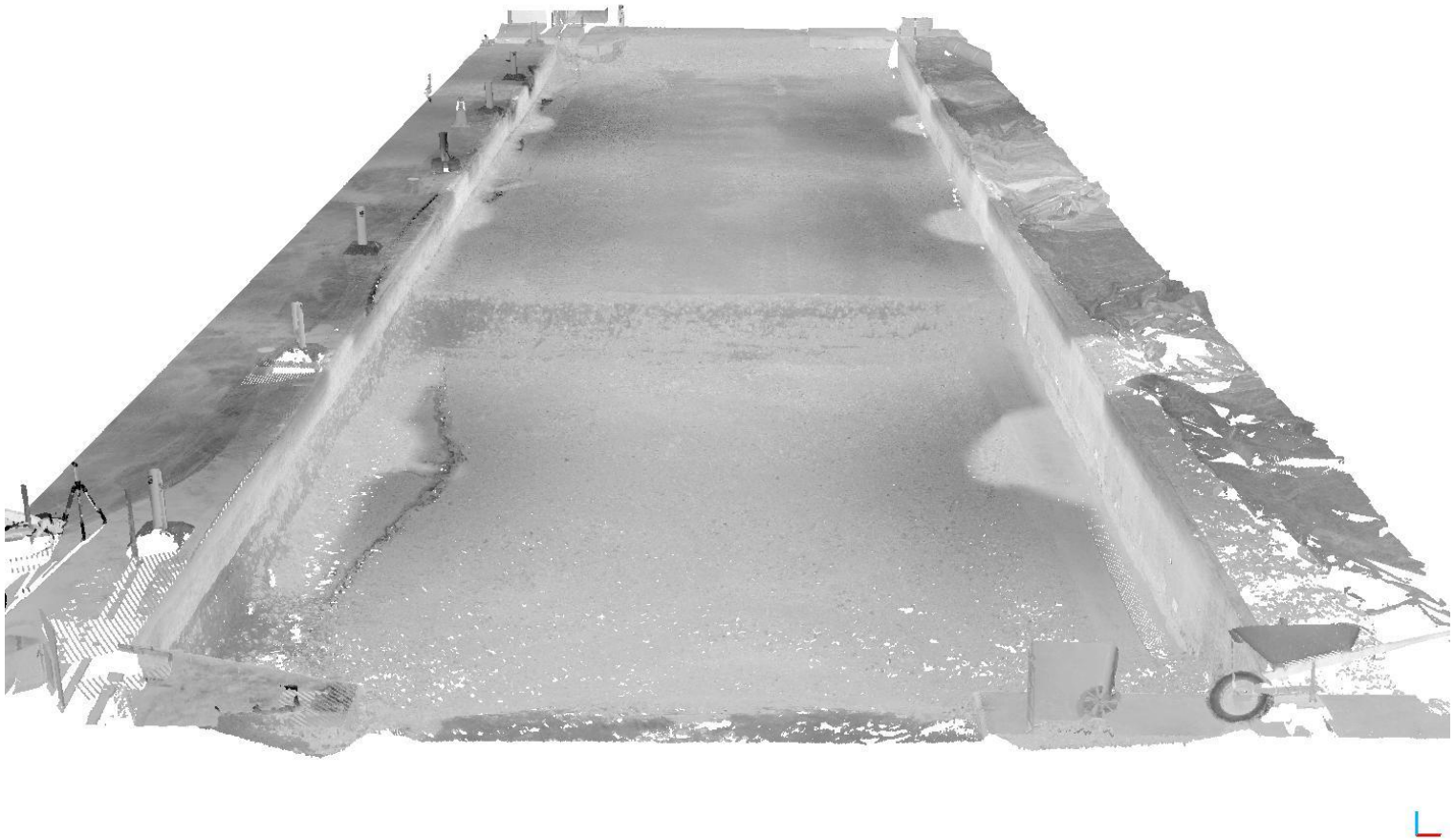

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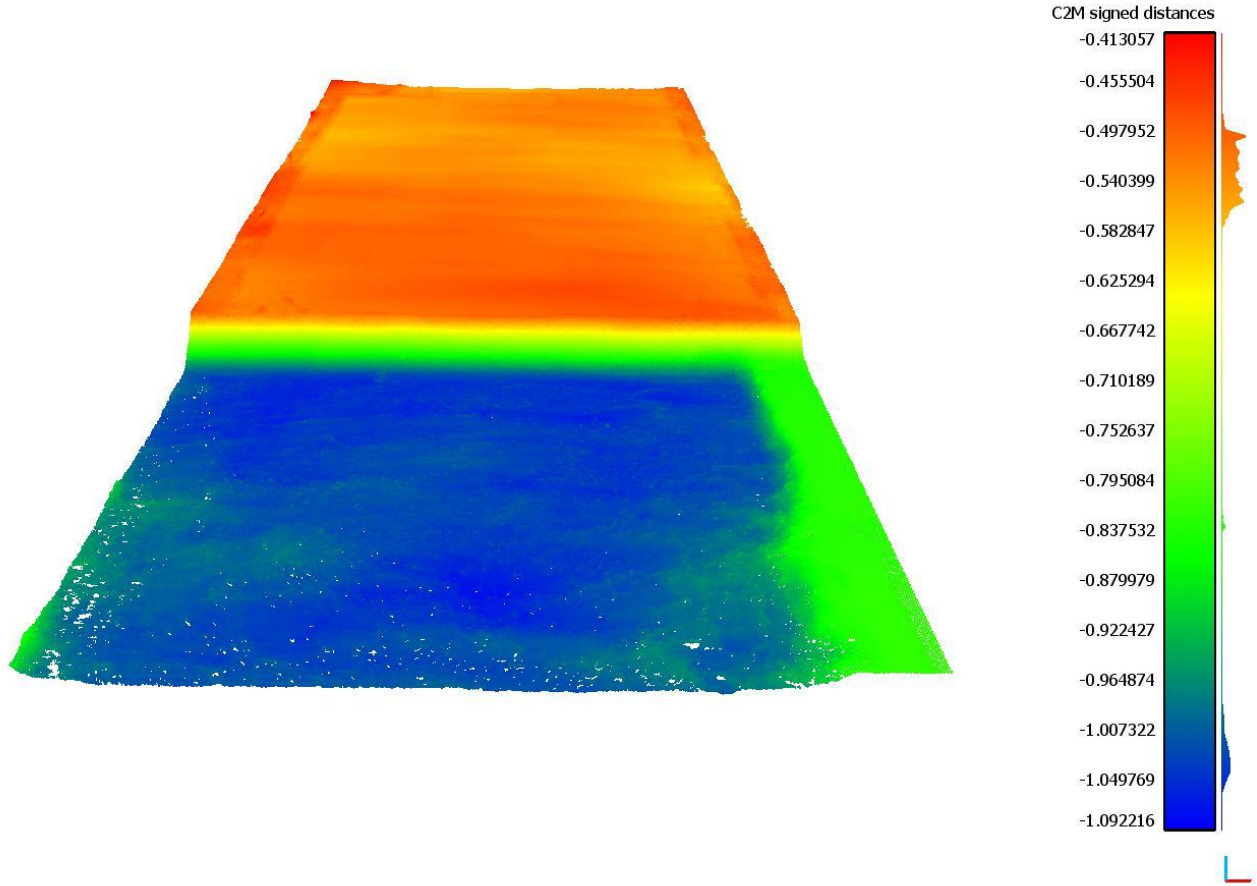

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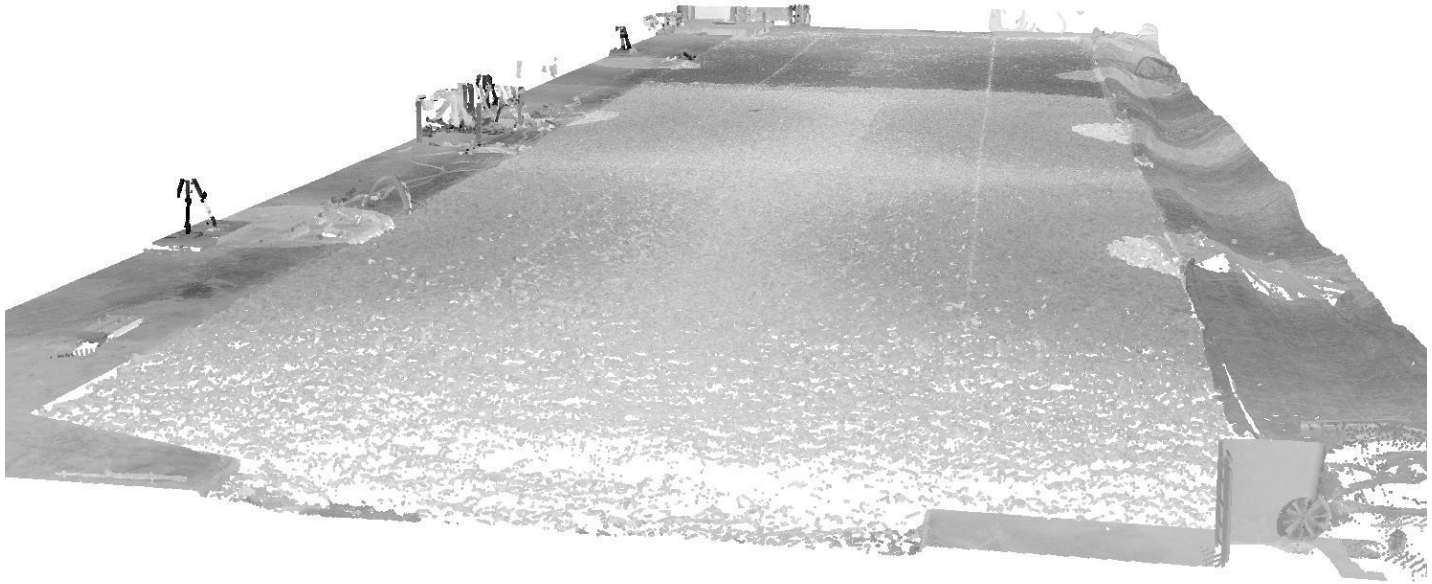

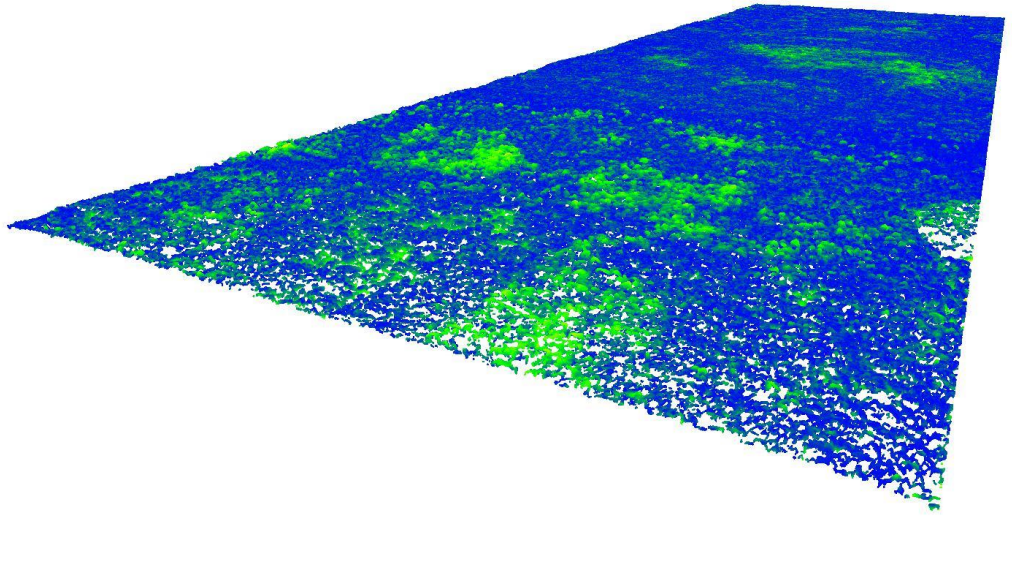

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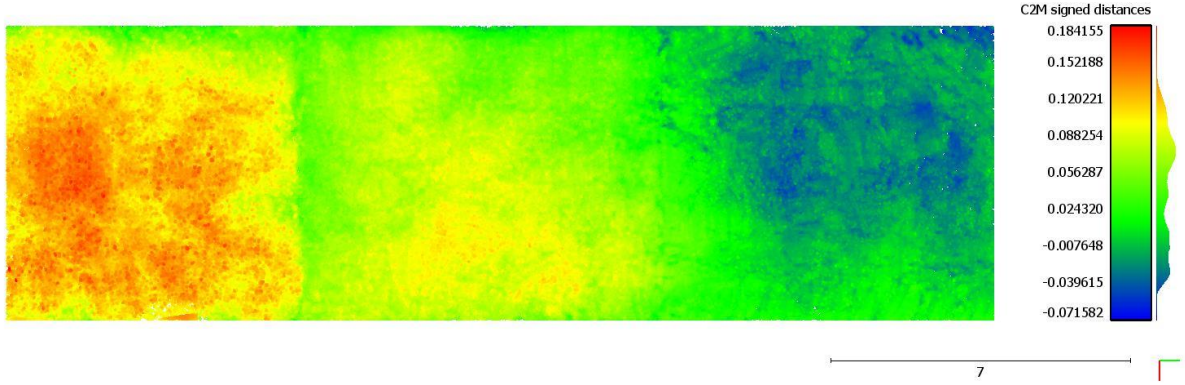
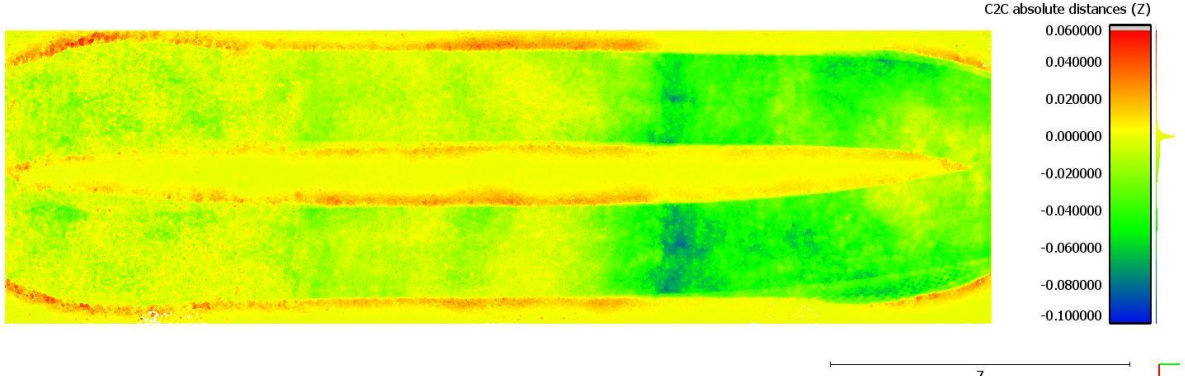
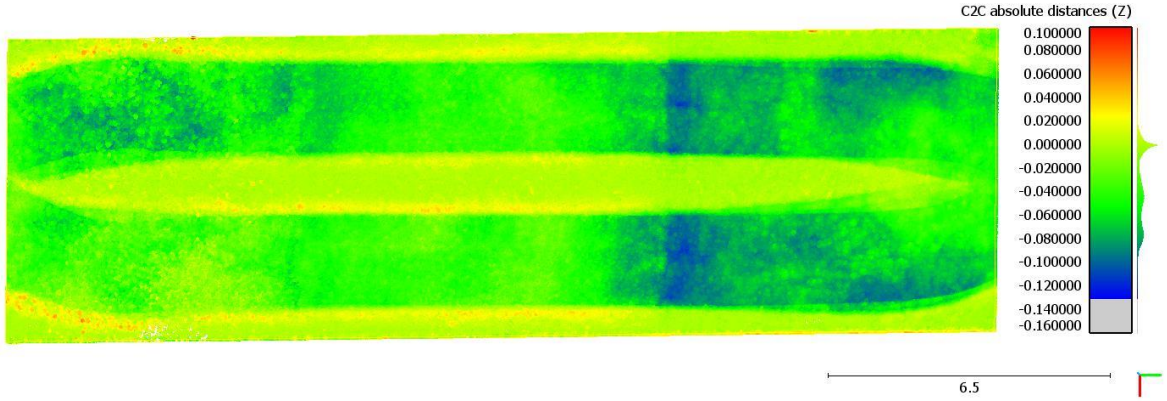


Before compaction



After first two static passes



After four vibration passes

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Roller compaction experiments | +8/32 first pass

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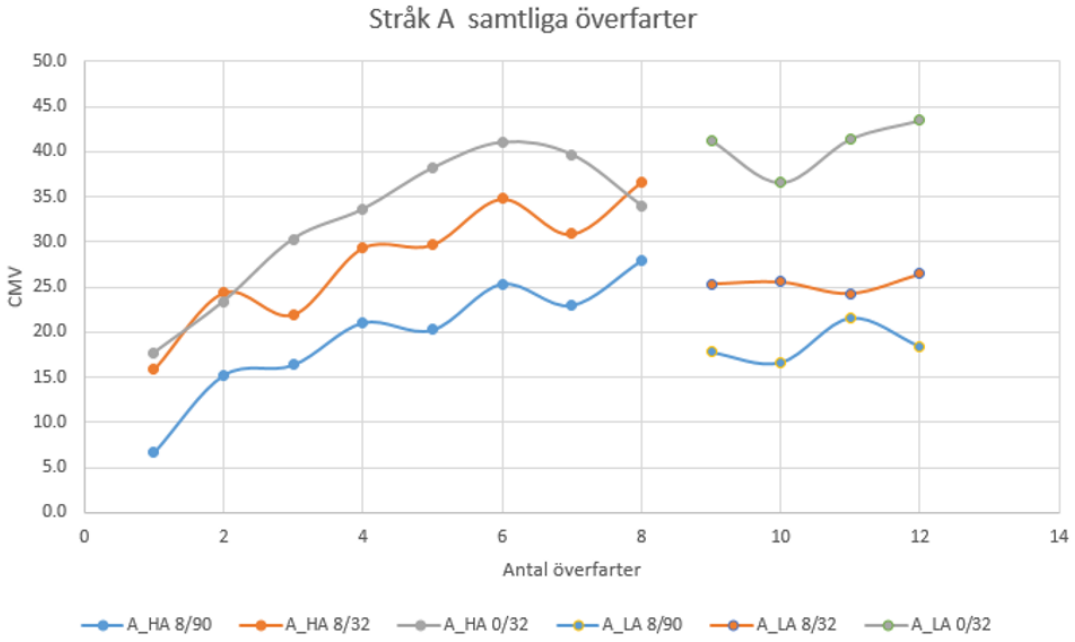
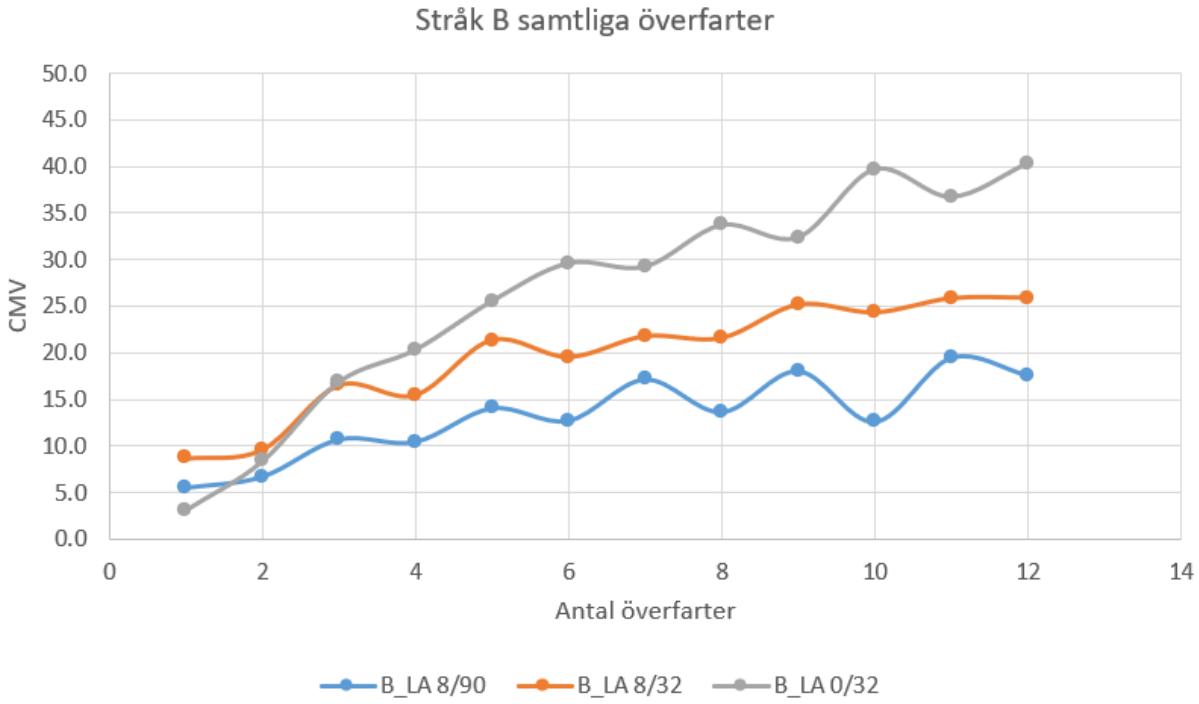
Roller compaction experiments | +8/32 11th pass



Figur 1: CMV (Compaction Meter Value) för 8 överfarter HA @ 26 HZ + 4 överfarter LA @ 33 Hz på de tre olika fraktionerna.



Figur 3: CMV (Compaction Meter Value) för 12 överfarter LA @ 33 Hz på de tre olika fraktionerna.

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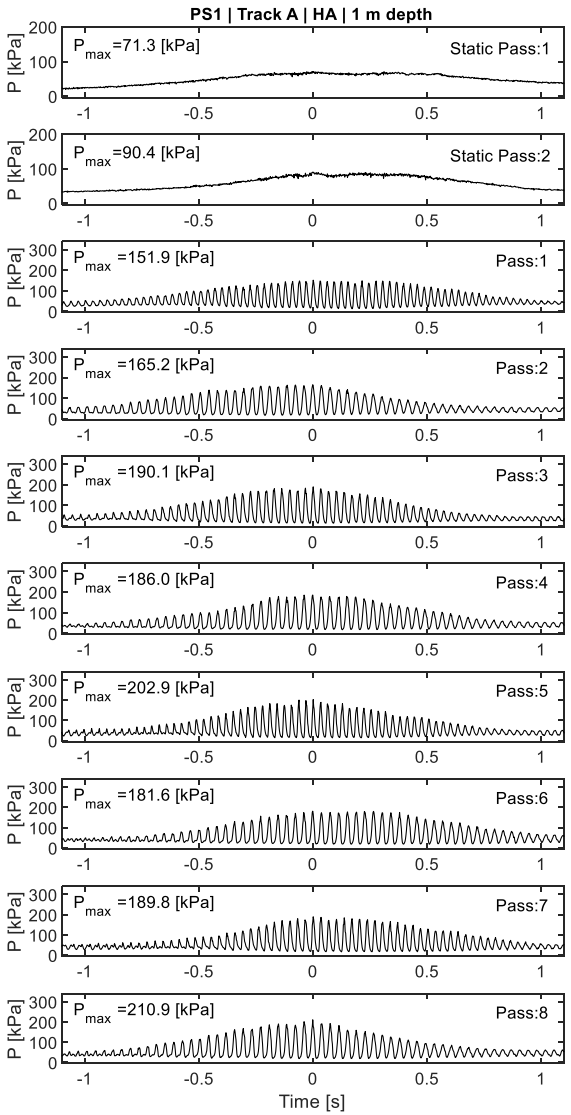
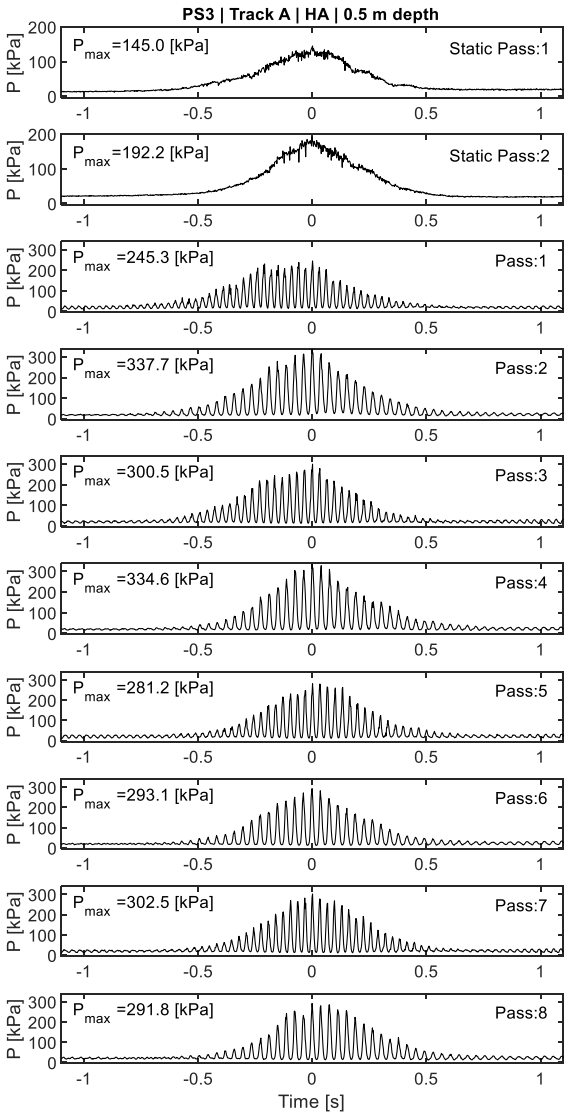
Roller compaction experiments | Ground pressure





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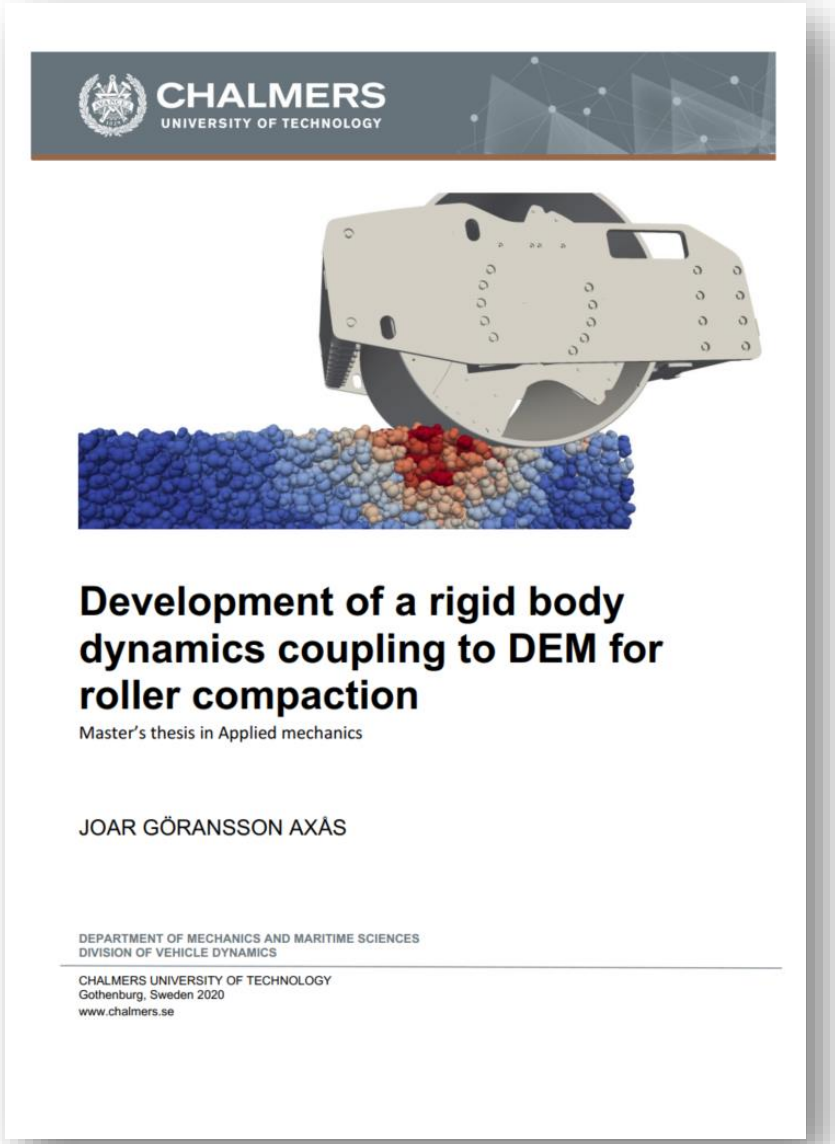
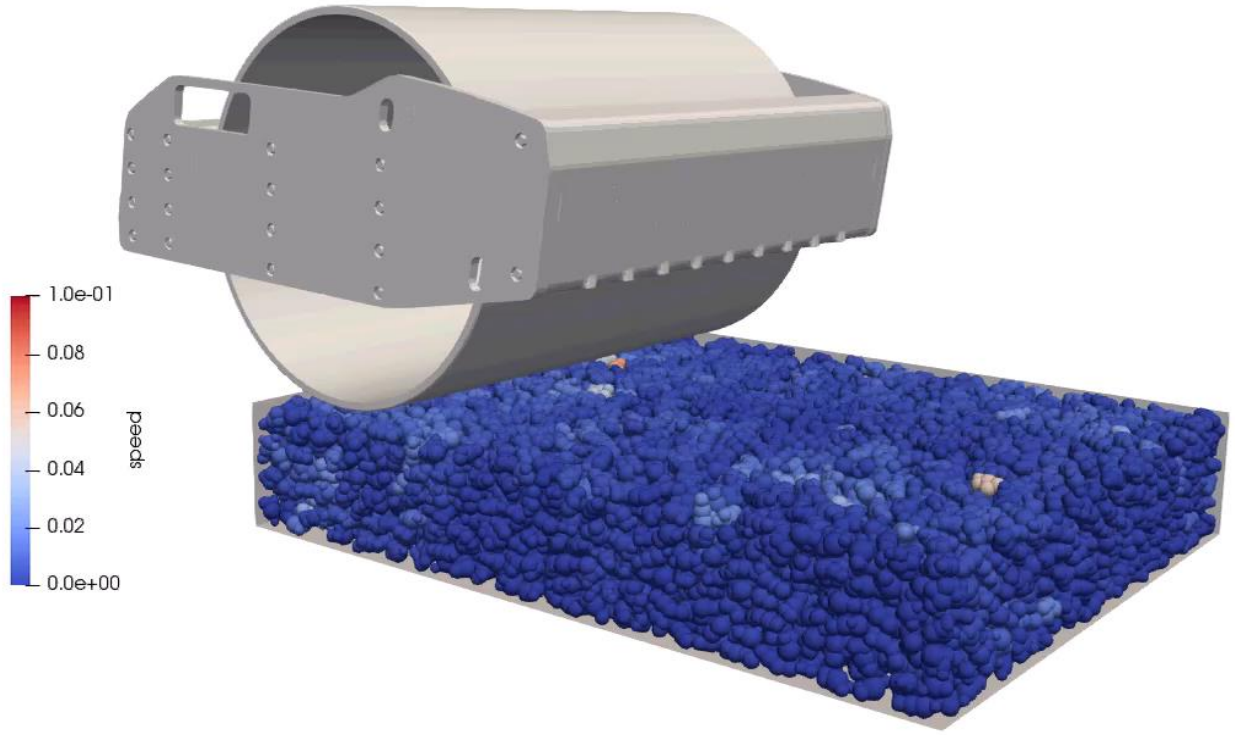
Roller compaction master thesis





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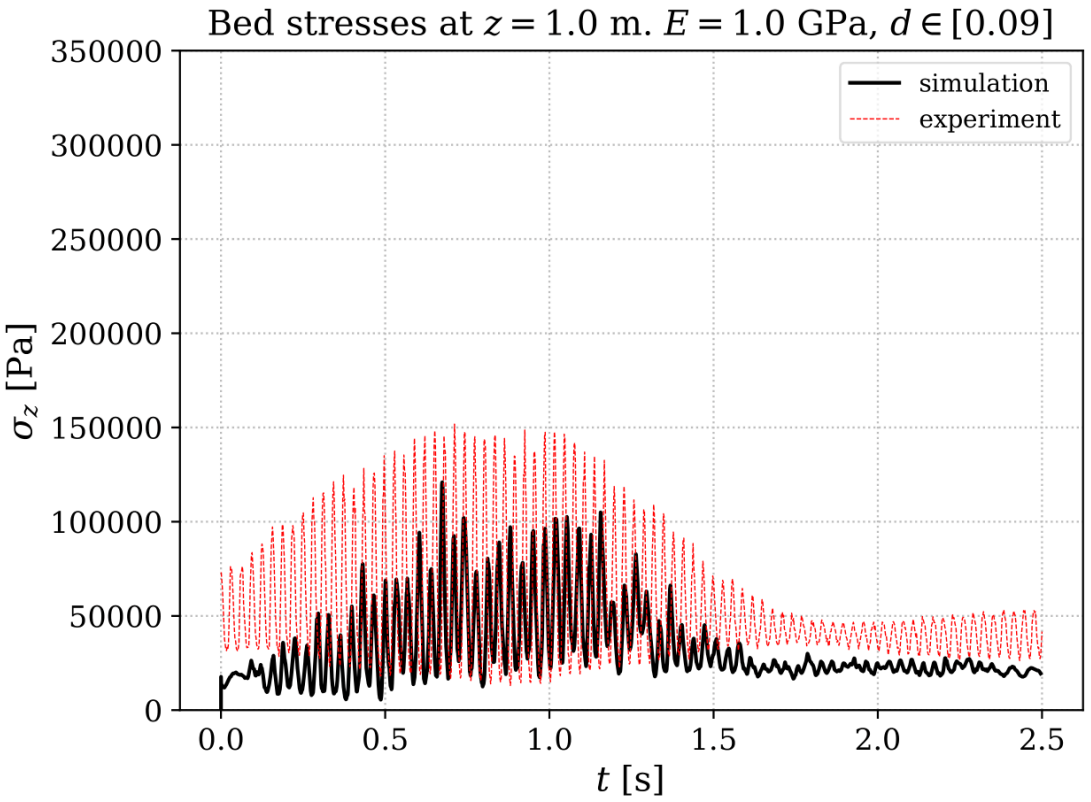

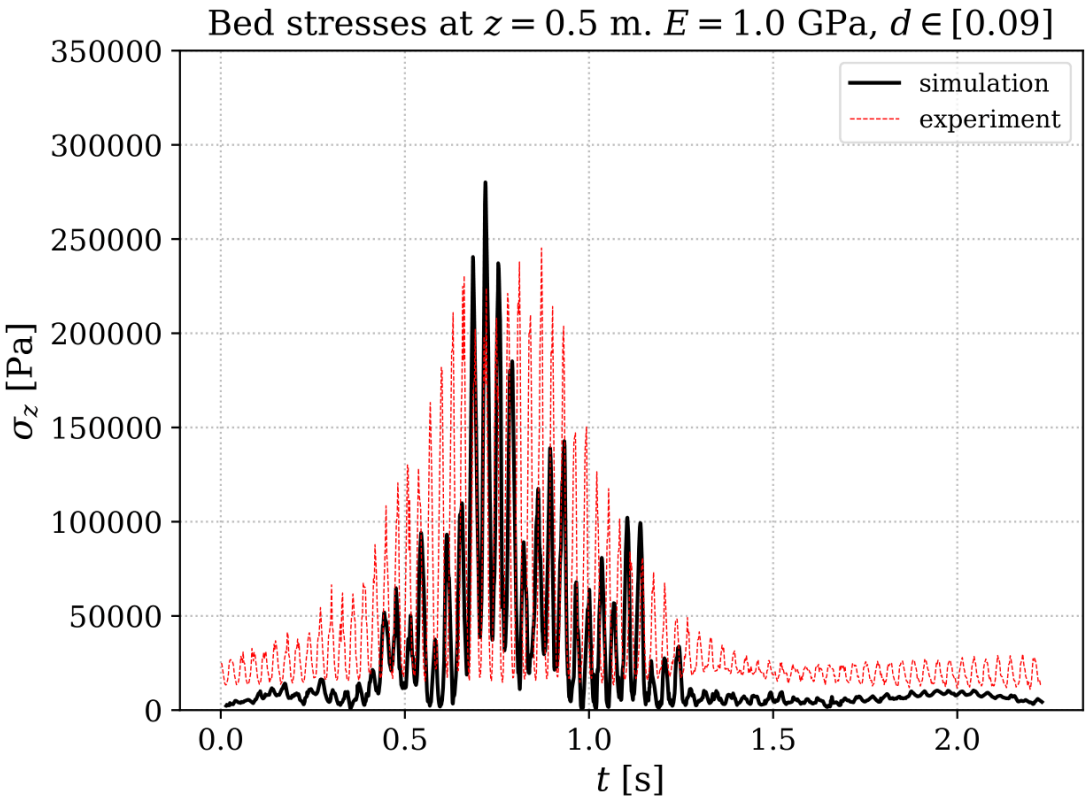

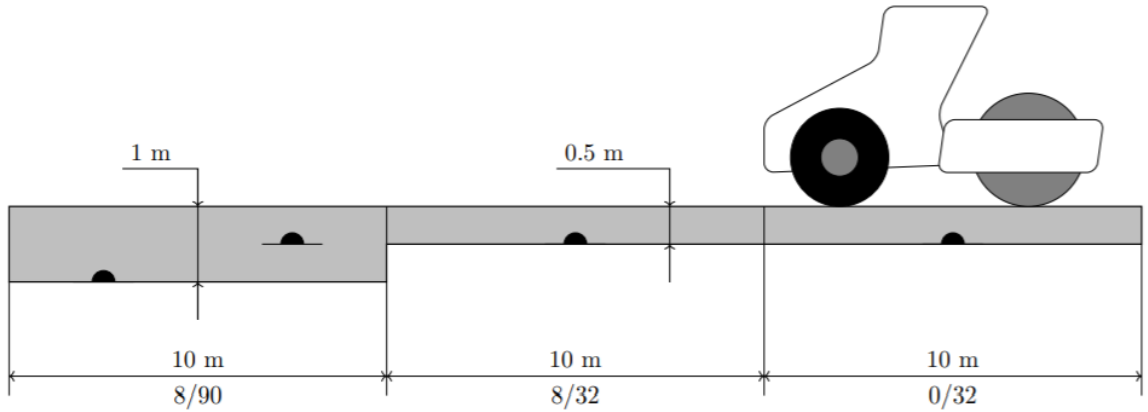

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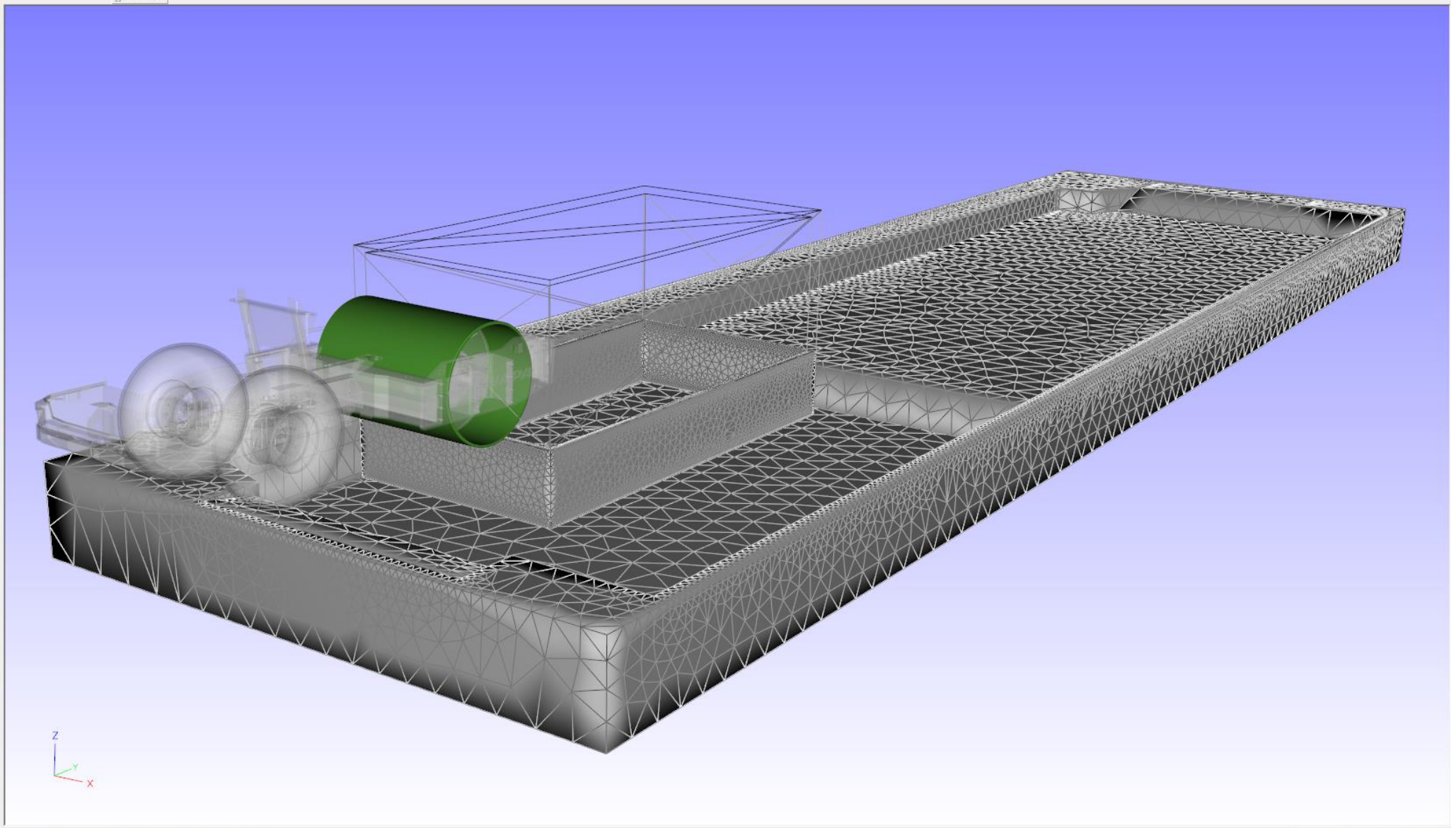
DR_SBUF2_scene - Industrial Path Solutions 3.10a4-295-g3a13ef68ec

File Edit Create View Graphics Tools Flexible Demify Windows Help

Scene

- Discrete Element Model
  - Materials
  - Interactions
  - Parts
  - ParticleModels
  - Distributions
  - Generators
  - Cases
- Static Geometry
  - Meshes
  - Meshes
  - Meshes
  - Meshes
  - CAD Geometries
  - Kansanshi_Phasell_Concepts
  - Chute
  - T_beams
  - Geometry Group 1
    - DECODE_V01_4753_Roller
    - DECODE_V01_4773_RollerInternalFram
    - DECODE_V01_5048_Excenter_L
    - DECODE_V01_5105_Excenter_R
    - DECODE_V01_4523_InternalStructure_I
    - DECODE_V01_4752_InternalStructure_I
    - DECODE_V01_2759_RollerFrame
    - DECODE_V01_3095_RearFrame
    - DECODE_V01_4188_RearAxle
    - DECODE_V01_4216_BackWheels
- Active Objects
- Mechanisms
- Simulations
- Measures
- Trash



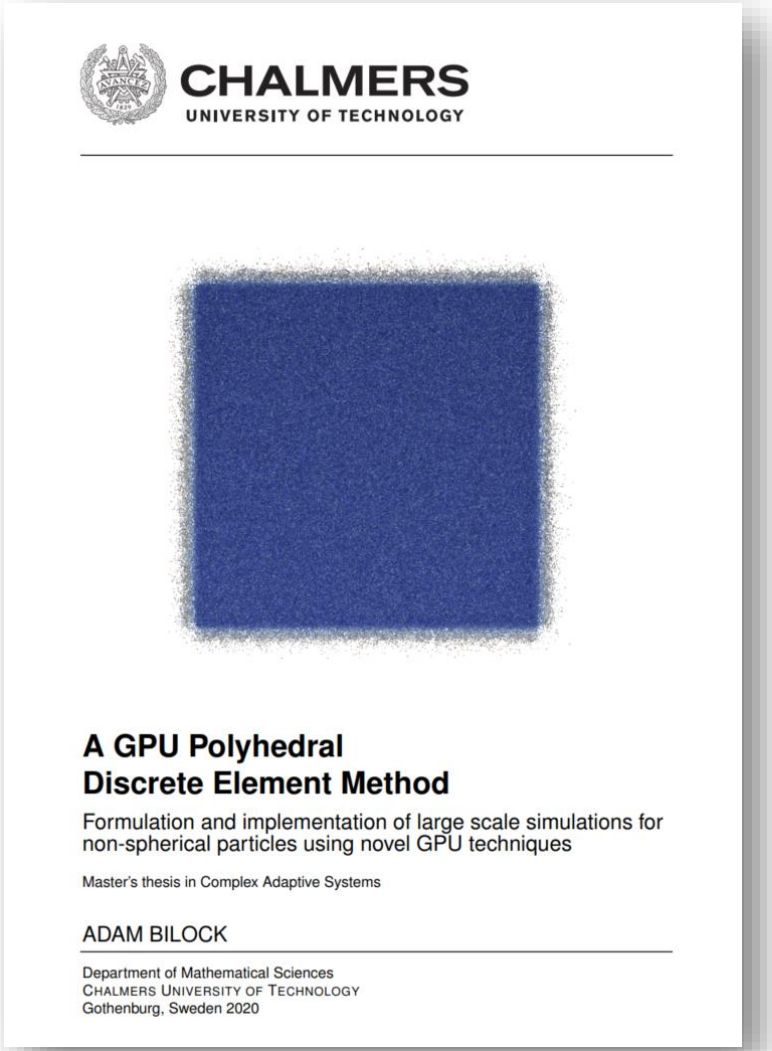
[10:51:08] DEM: To create tree view if not nullptr
[10:51:08] Connecting the tree view to the core for DEM

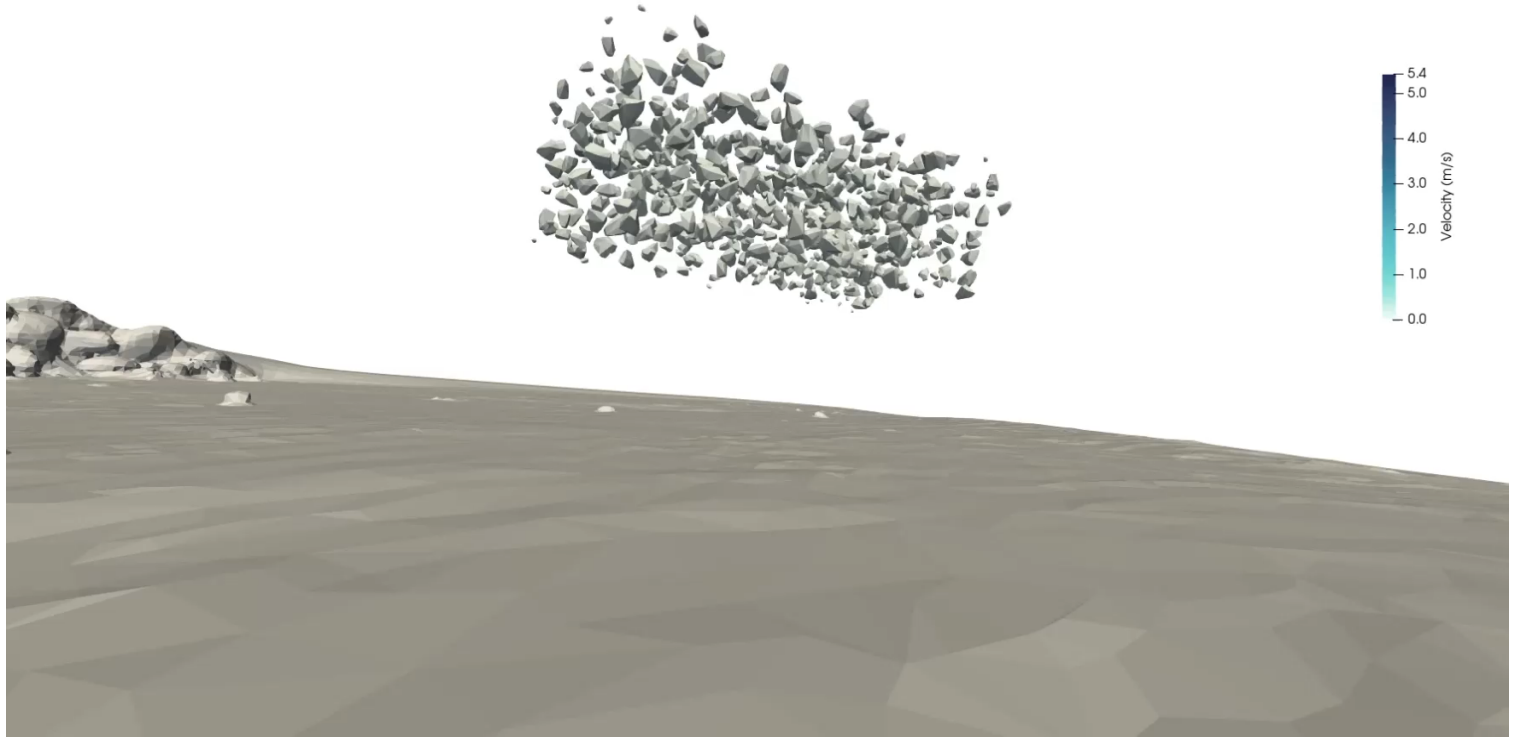
Ready.

Clear Log Window

Synchronize

Polyhedral GPU solver master thesis





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DIGIROAD

Simulation of handling and compaction of unbound aggregates in road construction

Planned case study 2021 – Differential compaction of UGM layers due to construction traffic

Scope:

Investigate the effects of articulated hauler tire compaction of base course layer on the final compaction performance and differentiation from the nominal compaction response

SBUF board decision w.44

Method:

- Multi-camera system
- Laser 3D scanning
- Material sampling
- Ground pressure load cells
- Static load plate test & CMV
- Material: +0/-32
- 2 Tracks (with/without traffic)
- DEM/MBD Co-Simulations

Info:

- SBUF project support
- Project Idea: Martyn Luby, Volvo CE
- Project Owner: NCC
- Project Leader: Kristoffer Hofling
- Project partners: FCC, Volvo CE
- Test location: NCC Stenungsund
- Machinery: e.g. Volvo SD135B, A45G
- Time: Best case scenario spring 2021

Stenungsund

"The first project that we had this discussion was years ago when I worked for NCC and we were tendering for a job in Malmö harbour.

Then since I worked for Volvo the discussion has come up on and off with contractors using our compaction system who see these areas as they get extremely high CMV values when they pass over them with the roller."

SBUF
SVENSKA BYGGBRANSCHENS UTVECKLINGSFOND
The development fund of the Swedish construction industry

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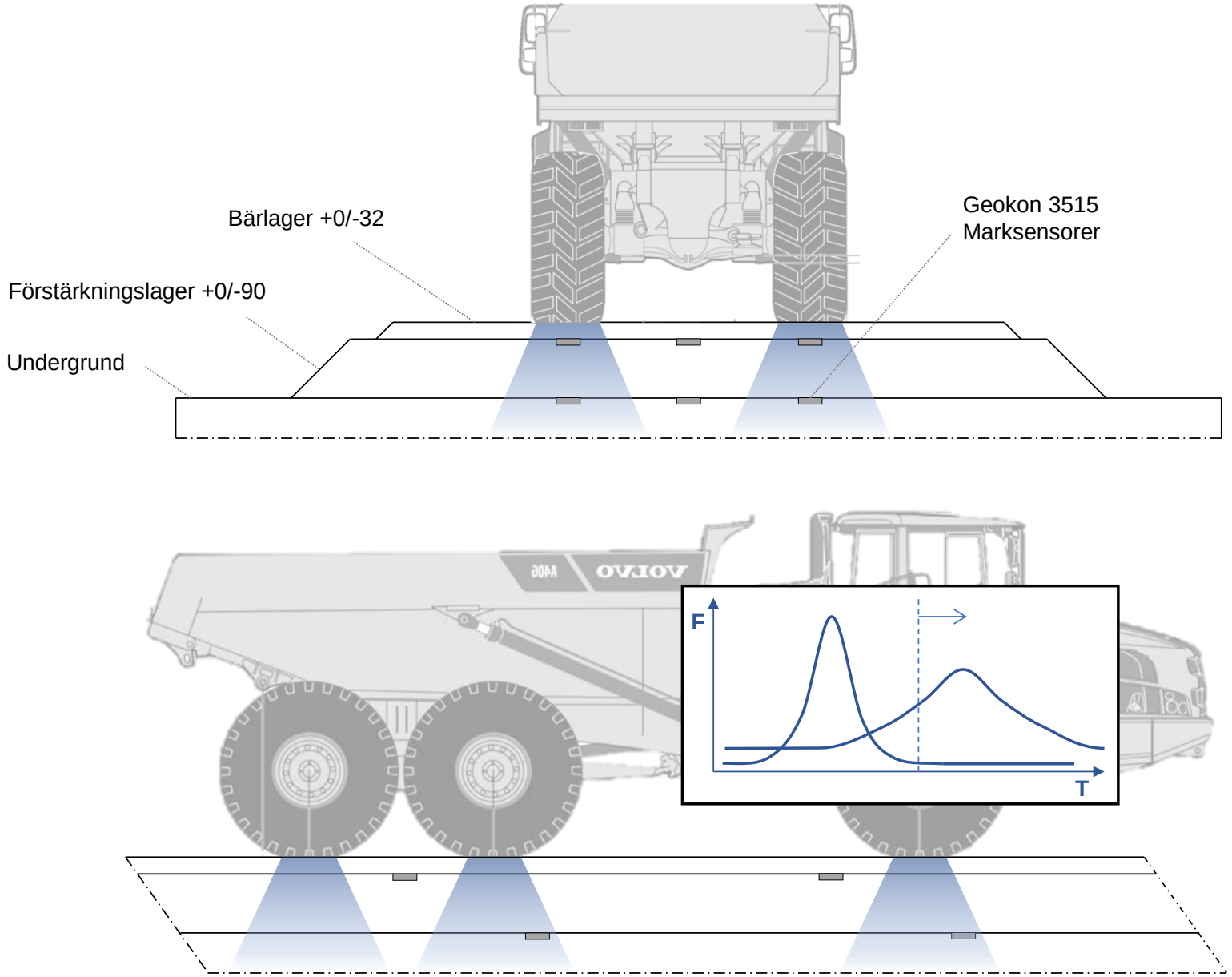
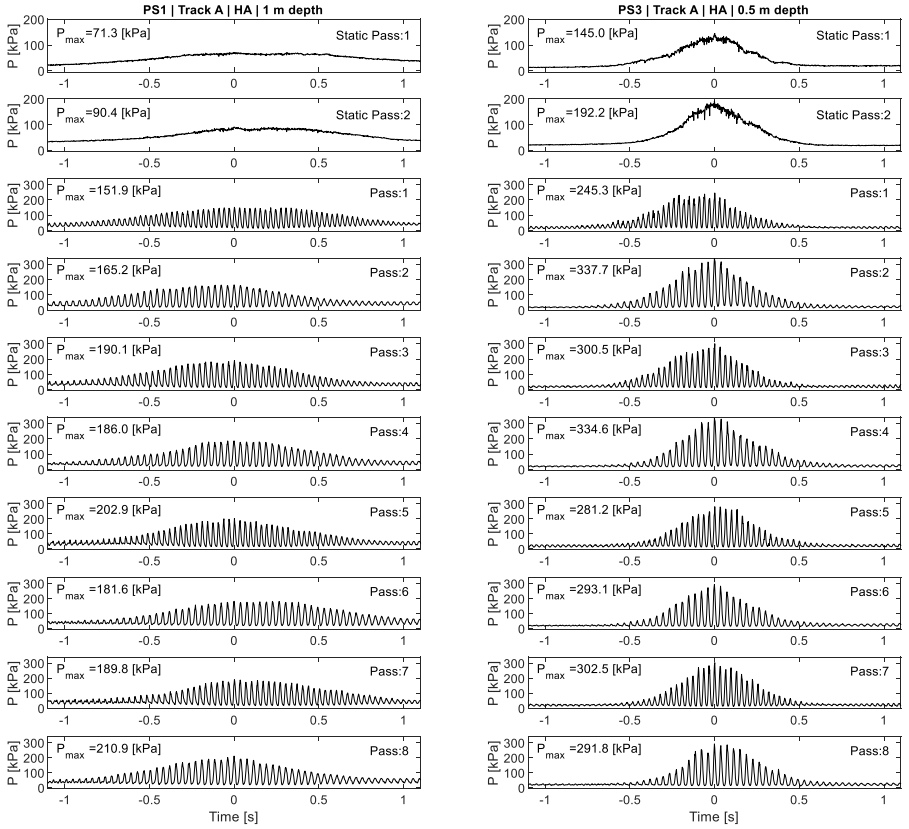
Johannes Quist





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Kommande utlysning | Idéer

- Öppna för samarbete inom simulering, modellering, optimering
- “DigiRoad II” i lokal stadsmiljö

  Exempel:

  - Utmaningar i gatumiljö, ex. bibehållen kvalité efter arbeten för access till vatten/avlopp/fjärrvärme
  - Kvalitetseffekter, styvhet och deformation vid olika typer av beläggning i anslutning, marksten-bitumen-betong och dess interaktion med obundna lager.
  - Hantering och kompaktering av obundna lager i närhet av infrastrukturell geometri såsom betongrör, spårvagnsspår etc.

Sammanfattning

- Projektet fortskrider enligt plan med viss justering
- Fullskalestudier
  - NCC (genomförd)
  - Dynapac (pågår)
  - Volvo CE (planeras)
- Demonstrator (Demify) redo att levereras till konsortiet
- Fokus på publicering
- Spridning av projektresultat

User interfaces

Python API

- Advanced case configuration
- Batch simulations and DOE
- Optimization
- Run on HPC cluster

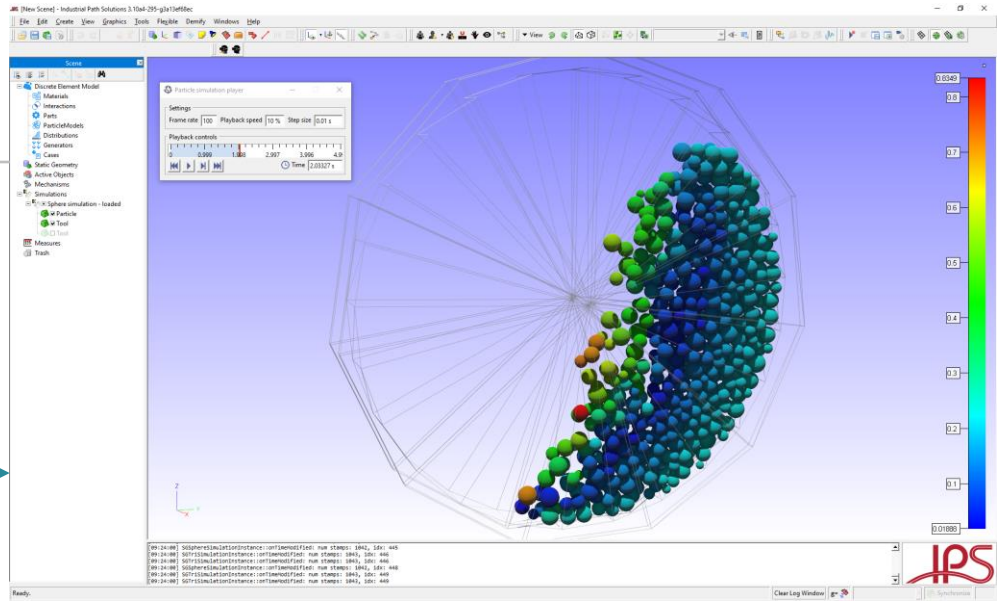
```
100  ##########################################################################
101  # Build the basic simulation data
102  ##########################################################################
103  options.get_logger(options.LogLevel.Verbose,
104                     name=os.path.join(args.outputfolder,
105                                       "log.solver.ft4.fine.long"))
106
107  particle_mat = m.Material(name="particle_mat",
108                            density=8200,
109                            youngs_modulus=args.youngs,
110                            poissons_ratio=0.25)
111
112  tool_mat = m.Material(name="tool_mat",
113                        density=7500.0,
114                        youngs_modulus=args.youngs,
115                        poissons_ratio=0.25)
116
117  pp_interaction = inter.HMDnnsTanHist(particle_mat,
118                                       particle_mat,
119                                       friction=args.mupp,
120                                       surface_energy=args.vdwpp,
121                                       friction_rolling=args.rfpp,
122                                       restitution=args.epp)
123
124  pt_interaction = inter.HMDnnsTanHist(particle_mat,
125                                       tool_mat,
126                                       friction=args.mupt,
127                                       surface_energy=args.vdwpt,
128                                       friction_rolling=args.rfpt,
129                                       restitution=args.ept)
130
131
132  if args.generator==0:
133    # Fill parameters which will later be modified
134    time_fill_end = 1.0
135    end_time = 1.5
```

Python case export

Load for visualization

Windows GUI on IPS platform

- Visualization & Post processing
- Geometry
- Kinematics
- Iterative case development



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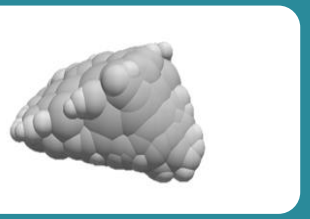
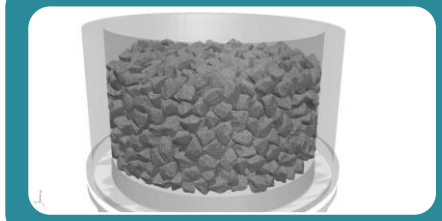
Verification and validation process

	Numerical	Experimental

 **Single particle**
•Micro mechanical
•Rigid body dynamics
•Shape representation
	• Convergence
	• Conservation
	  • Energy
	  • Momentum
		• Material property characterization
		• Error optimization

 **Multiple particles** •Flow dynamics •Macro-mechanical •Geometry & kinematics	• Convergence • Stability and robustness • Performance characterization	• Material ensemble optimization • Particle resolution optimization

 **Full scale**
•Flow dynamics
•Macro-mechanical
•Geometry & kinematics
	• Convergence
	• Simulation feasibility
	• Global system conservation
	  • Energy
	  • Momentum
		• Global optimization of process
		• Machine-particle system optimization