SCIENTIFIC AND TECHNICAL CO-OPERATION

between

Graz University of Technology (Austria)

and

Faculty of Geotechnical Engineering

(University of Zagreb, Croatia)

Testing and modelling of mechanical behavior of biodryed waste as a Waste-to-Energy prerequisite

Hrvatska zaklada za znanost

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Vice-dean for teaching at the Faculty of Geotechnical Engineering

Crain crushing

The mechanism involved in the refuse settlement takes place in following stages.

- Mechanical – distortion, bending, **crushing and reorientation** this similar to consolidation of organic soils.
- Ravelling- Movement of fines into large voids.
- Physico-chemical changes -Corrosion, oxidation and combustion.
- Bio-chemical decomposition -Fermentation and decay

No papers???

Void ratio

DEM - macro and micro particles

- porosity betwen two macro particles
- porosity of individual macro particle

- Waste – exactly the same property

  - untreated municipal solid wase - coca-cola cans
  - For MBT waste - not so pronounced but there might still be particles with their own woid – like for example bottle cap

Possibilities for project proposals

- through Croatian Science Foundation
- through UKF fund – diaspora?
- through Horizon 2020
- through ESF
- through KIC Raw Materials – calls at the begining of each year – Bratislava

EIT RawMaterials, initiated and funded by the EIT (European Institute of Innovation and Technology), is the largest and strongest consortium in the raw materials sector worldwide. Its vision is to develop raw materials into a major strength for Europe. EIT RawMaterials unites more than 120 partners from leading industry, universities and research institutions from more than 20 EU countries.

https://eitrawmaterials.eu/

UNIZG, TU Graz and University of Miskolc;

Széchenyi István University, Gyor

Possibilities for project proposals

- CRO NGI - The Croatian National Network of Infrastructures (CRO NGI) is a distributed computing environment, consisting of processor and data resources, located in the hubs within the Republic of Croatia.

  Currently, a total of 1,868 processor cores, 36 graphics processors and 205 TB of data space are available to users. CRO NGI is available for all scientific and research projects funded entirely or partially from the State Budget of the Republic of Croatia. In addition, CRO NGI is associated with the world's largest global grid project EGI (European Grid Infrastructure), enabling users to access EGI resources.

Erasmus +?

Table of Contents

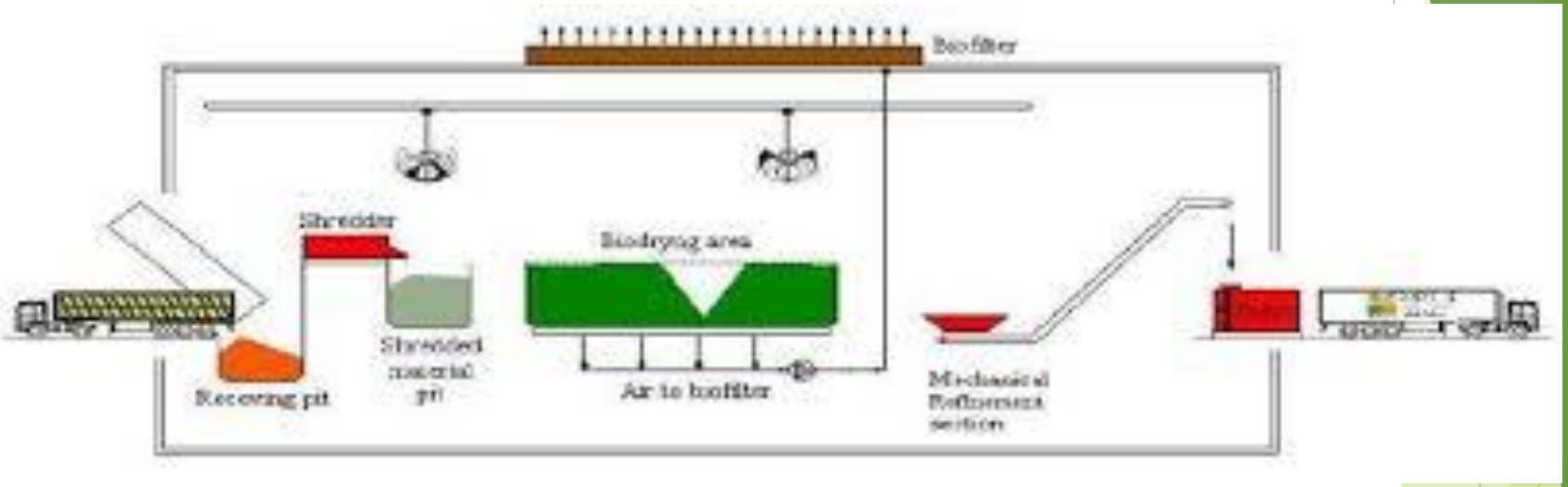
What is a biodrying?

Biodrying is an aerobic process during which the moisture content of waste is reduced while the degradation of organic waste is kept to a minimum.

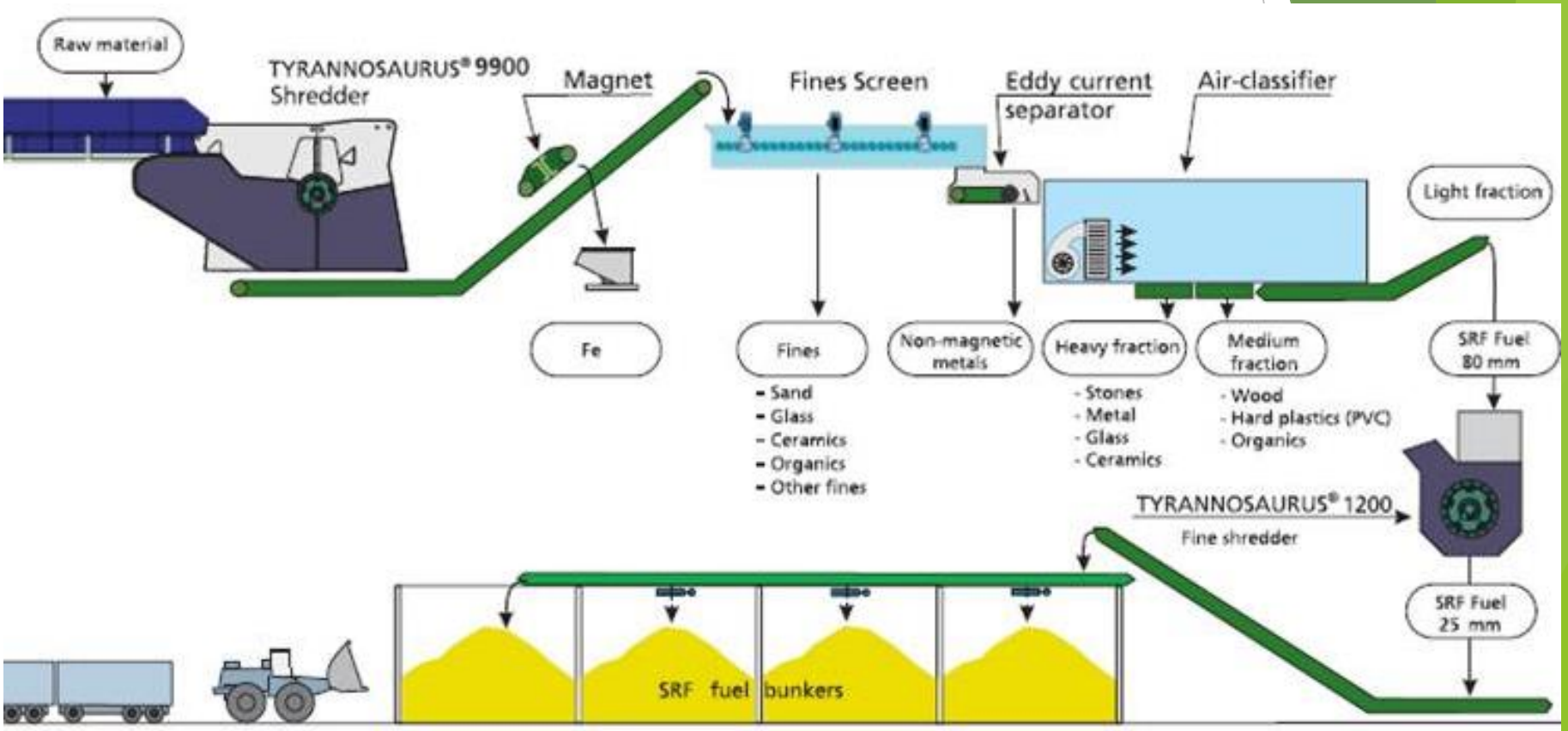
The main purpose of the biodrying process, as opposed to the composting process, is not to maximize the degradation of organic material, but to bring about the biodegradation of organic waste to an extent sufficient to produce biologically induced heat to dry the waste via evaporation.

In general, the MBT plant biodrying reactor accepts unsorted, shredded municipal solid waste. Due to a forced aeration, dried waste material suitable for subsequent mechanical processing is obtained within the reactor. The prime goal of subsequent mechanical processing is extraction of recyclable materials, production of refuse derived fuel (RDF) and separation of organically rich fine-grained fraction which is suitable for landfilling.

What is a biodrying?



What is a biodrying?



What is a biodrying?

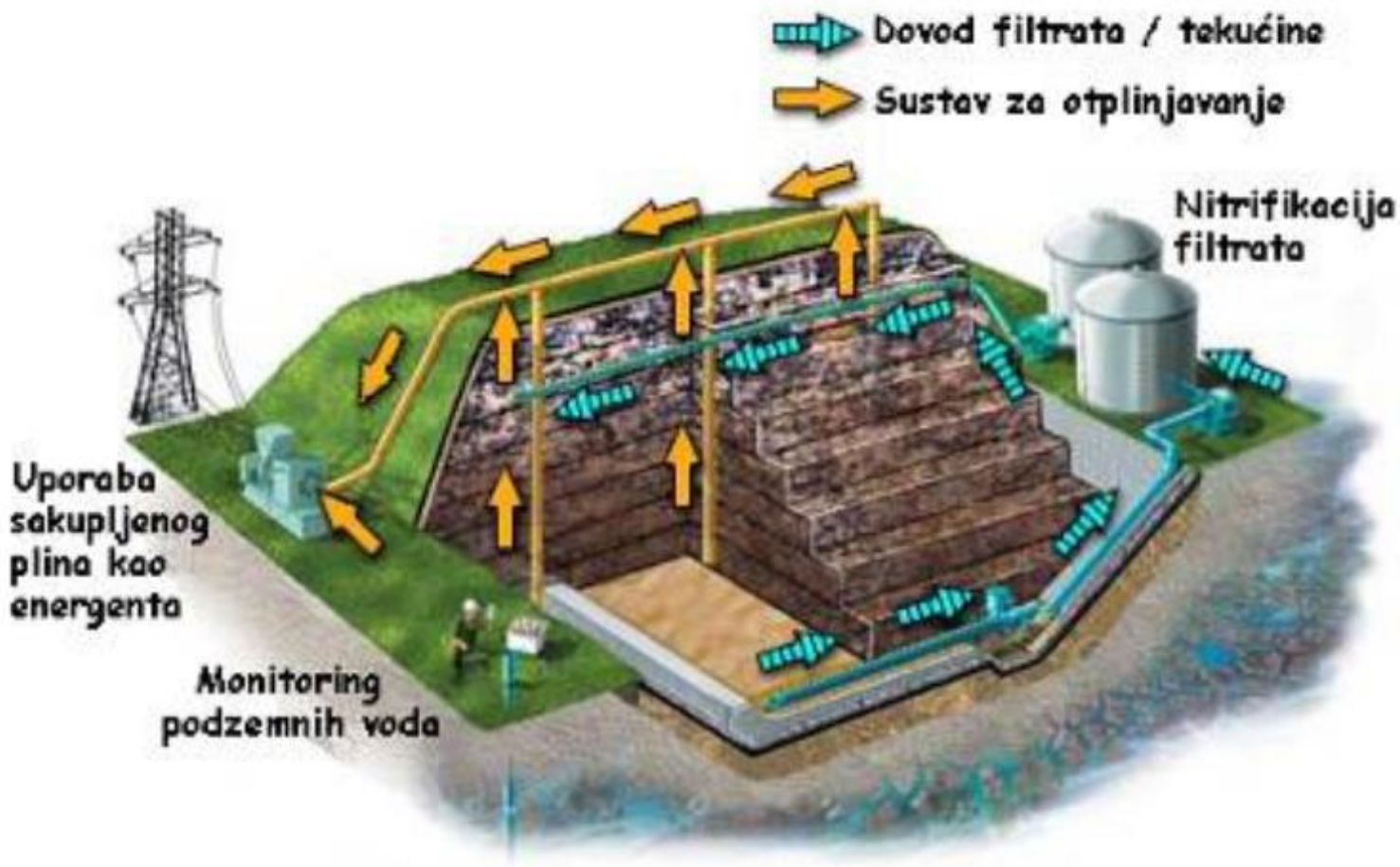
What is a bioreactor landfill?

Once disposed, organically rich, fine-grained fraction is once again submitted to the wetting process in order to accelerate the decomposition process and to increase the biogas production. Generated biogas is then extracted from the landfill body and used as an energy source for generation of thermal and/or electrical energy.

In comparison with traditional “dry tomb” landfills, bioreactor landfills offer significant advantages with respect to the accelerated waste degradation as well as increased revenues due to increased biogas production.

Therefore, the bioreactor landfills are quite often presented as a well-known and proven solution. However, the geotechnical issues which have to be considered in order to secure the proper functioning of bioreactor landfills are often neglected.

What is a bioreactor landfill?



What is a bioreactor landfill?

The main geotechnical challenge in the design of a bioreactor landfill is to secure constant recirculation of leachate through landfill waste body. This procedure is significantly altered due to a fact that hydraulic conductivity of biodryed and mechanically treated waste, with respect to the non-treated waste, is significantly reduced. In fact, biodryed waste material possess hydraulic properties comparable with peat and clays.

Furthermore, due to a degradation of waste, the density of deposited waste material increases and therefore the hydraulic conductivity of waste is decreased even further.

Reduced permeability, in combination with high saturation levels, can have significant impact on biogas extraction potential, and consequently to reduce the anticipated revenues.

Furthermore, the reduced gas extraction efficiency might also increase the cost of the monitoring program in the after-care period. In addition, not only hydraulic conductivity, but other geotechnical parameters as well (shear strength and compressibility) are submissive to changes due to a degradation process.

Why is mechanical behaviour of byodried waste material important for us?

Currently, there are two operating MBT plants in the Republic of Croatia whose technological process ends up with biodryed organically rich waste stream which is suitable for disposal on bioreactor landfill.

In spite of the fact that, according to the Croatian legislative, it is allowed to operate a bioreactor landfill, and even though two MBT plants with the product suitable for disposal already operate in Croatia, bioreactor landfills in Croatia still does not exist.

An insufficient number of experimental data related to the geotechnical parameters of biodryed organically rich waste material is one of the reasons why the bioreactor landfills still does not exist in Croatia. This, as well as the lack of the appropriate numerical model, can be highlighted as the main reasons for the absence of bioreactor landfills in Croatia.

Therefore, it is necessary to conduct a thorough experimental research progame and to develop an appropriate constitutive model.

Project goals and objectives…

The proposed project is primarily oriented to the refined experimental investigation and appropriate numerical modelling of the stress-strain relationship of biodryed MBT waste materials. The project is an extension of the former project “Characterization of municipal solid waste” funded by Croatian Ministry of Science, Education and Sports from 2007 till 2010.

Within the former project the general appropriateness of hypoplasticity to model settlement of MBT waste materials in a simplified manner has been proven in a first step. As only limited experimental results were available, a simplified hypoplastic version for oedometric boundary conditions was developed, which models the behaviour under vertical loading and unloading. It was demonstrated that for the calibration of the proposed simple hypoplastic model it is sufficient to conduct an oedometer test and to determine the angle of friction using a simple procedure by measuring angle of repose of the dry waste material.

The main goal of the proposed research is to develop an appropriate constitutive model for general 3-D stress paths as well as its adjustments with respect to the obtained experimental results for the biodryed MBT waste material.

Project goals and objectives…

Experimental investigation of stress-strain relationship of MBT waste material under low pressures (triaxial and direct shear tests) and high pressures (high pressure oedometer test) under drained/undrained, dry and water saturated condition, i.e.

- Triaxial compression tests to investigate the influence of pre-compaction (pyknotropy) and pressure level (barotropy) on the peak friction angle.
- Drained over-consolidated triaxial tests under monotonic loading and direct shear test on large specimens should clarify whether a critical friction angle and critical density exist or not. In this context, it should be clarified whether the concept of critical state soil mechanics can also be considered for MBT waste materials.
- Consolidation test in a large-scale oedometer with continuous measurement of produced biogas in order to determine the degradation stage
- Creep tests of pre-compressed dry and water saturated specimens using high pressure oedometer device to study the influence of pre-compaction and water content on the long term behaviour.

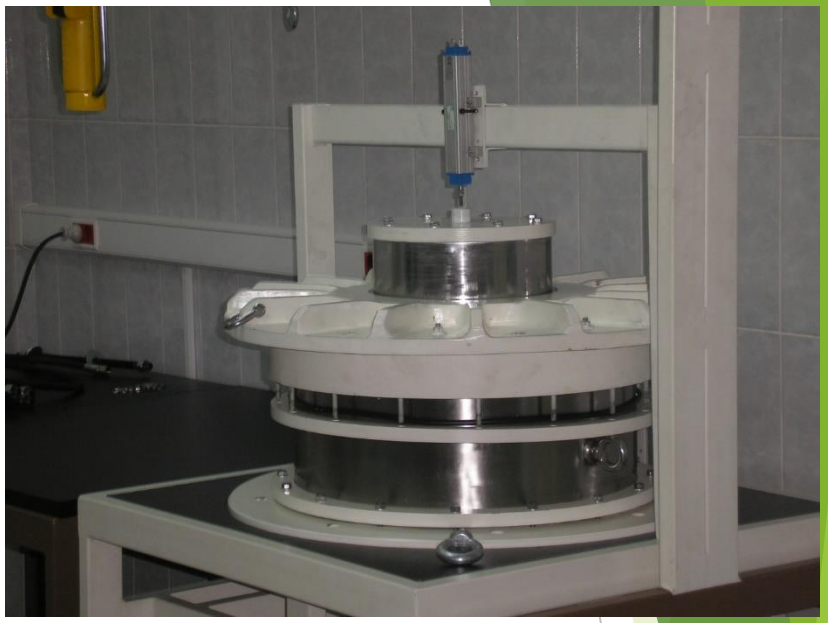
Experimental investigations of the pressure dependent limit densities and the critical density. These quantities are important for modelling the influence of density and pressure level on peak friction angle, contractance and dilatancy.

Numerical simulations using the proposed hypoplastic model to investigate its eligibility for describing the stress-strain and volume strain behaviour obtained in experiments. For practical application of the hypoplastic model this task should also clarify the required minimum number of constitutive parameters and experiments.

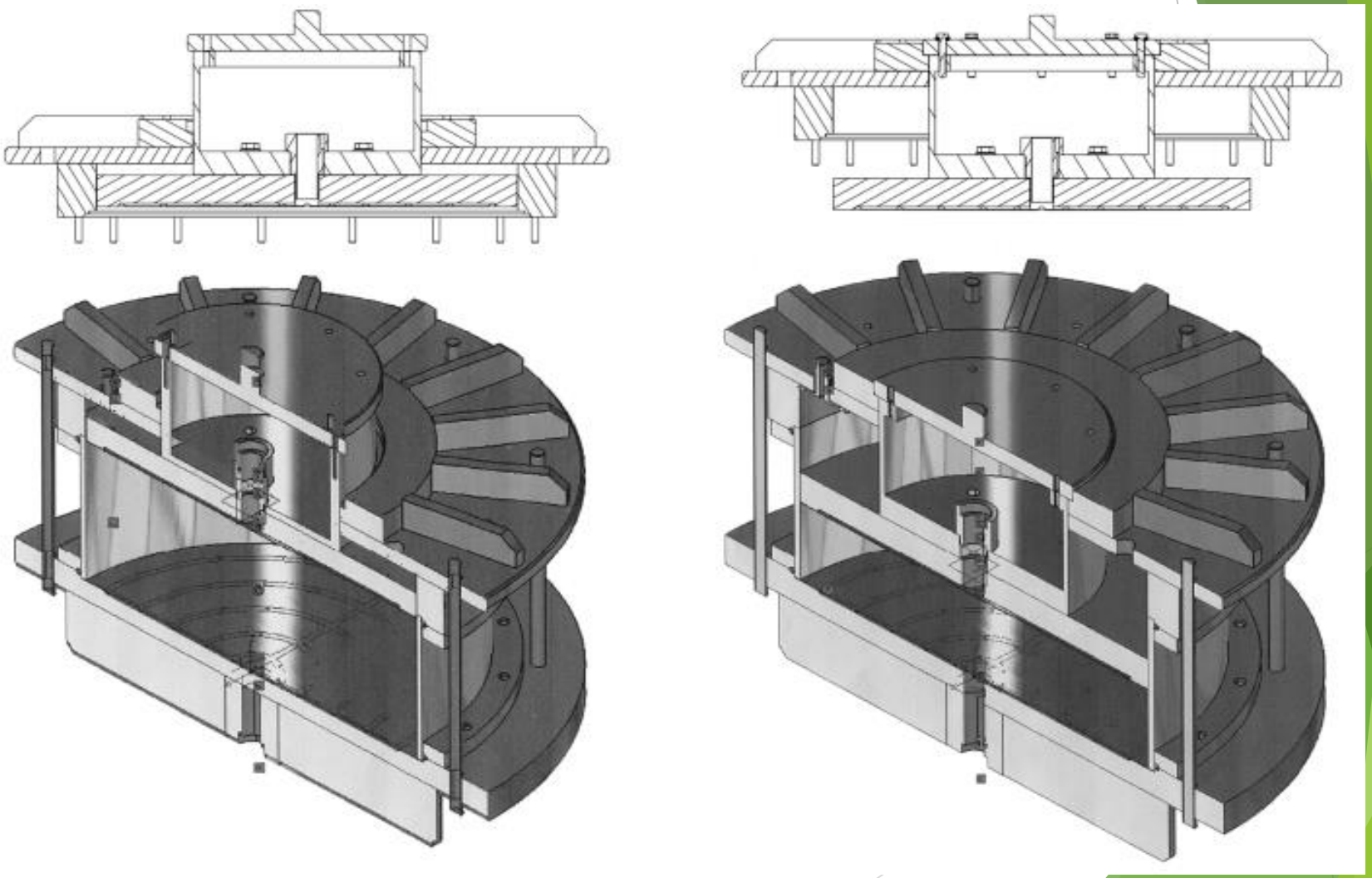
Large oedometer

The apparatus consists of a “loading frame”, pressure cylinder, lower and upper lid, sliding rail with pressure plate, a computer-controlled hydraulic loading actuator, an oedometer cell ring, two drainage composite plates, displacement and pressure transducer, computerized data acquisition system, two o-rings and worktable with hoist.

Large oedometer



Large oedometer



Large oedometer

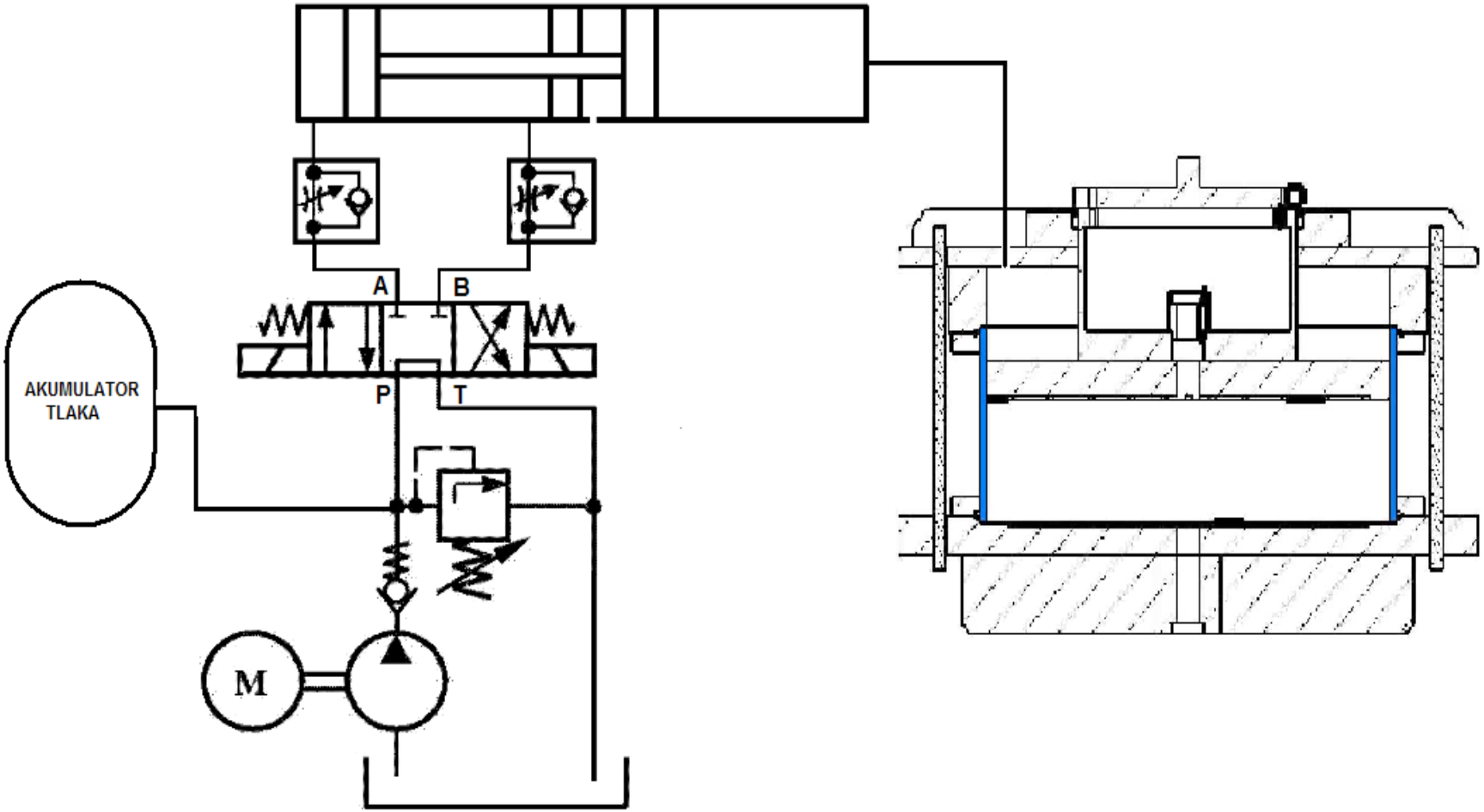
A torus rubber membrane, fitted between the upper lid and the pressure plate, is used for transmission of the load to the specimen. The membrane is pressurized by the hydraulic actuator, which means that the membrane actually acts as a “loading frame”.

Hydraulic odeometer?

The membrane is a modified car tube with dimensions 120 R12 70. The original air valve was removed, while the created hole was sealed. Two new vulcanized vents were installed on the outer perimeter of the membrane. The process of gluing takes approximately 24 hours. Installed vents can sustain pressure up to 3000 kPa.

Within this project proposal the modification of the large-scale oedometer cell is anticipated. The torus membrane will be replaced with new vertical loading system. The empty space obtained with removal of torus membrane will be used to measure the amount of generated biogas during consolidation process.

Large oedometer



Large oedometer

Large oedometer

Two main problems were identified during the tuning phase:

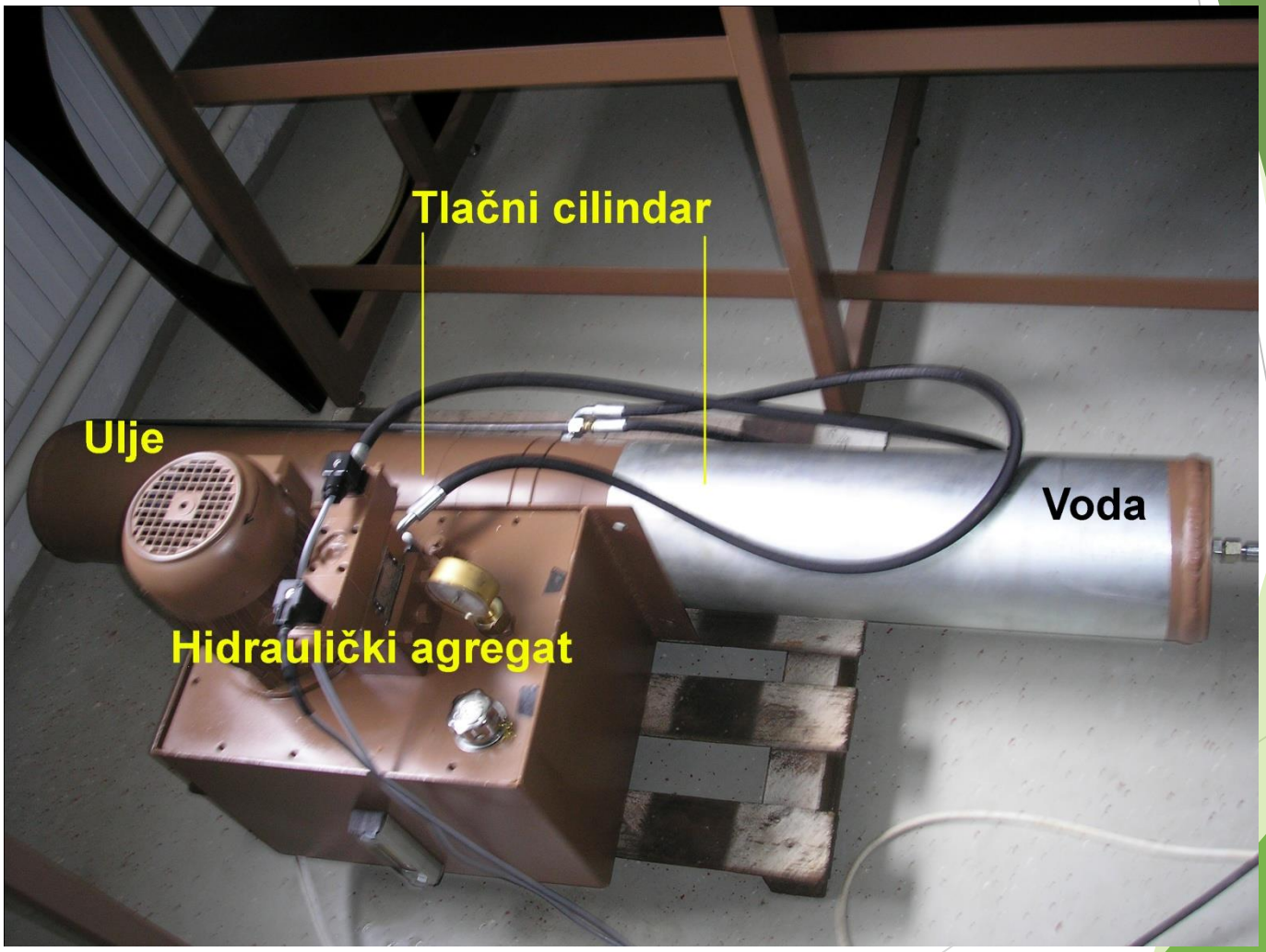
- tearing of the torus rubber membrane at large displacements
- uncontrolled pressure strokes.

High friction forces between membrane and sliding rail prevented smooth sliding of rail through membrane and caused uncontrolled deformation and finally rupture of the membrane. To reduce friction, the membrane was wrapped with the thin HDPE membrane, since this type of material has a tendency to exhibit less friction with the increase of normal force.

Pressure strokes have been reduced with the installation of a pressure cylinder between the rubber membrane and the hydraulic actuator. Half of the cylinder is filled with oil and the rest of it is filled with water. Part of the cylinder filled with oil is connected to the hydraulic actuator, while the second part of the cylinder is connected to the membrane. The main benefit of the mounted cylinder was in more reliable and more precise control of pressure in the rubber membrane due to a large amount of fluid which caused the cylinder to act as a damper of pressure strokes. Additional benefit in a case of accidental tearing of the rubber membrane is that laboratory floor could be soaked only with water which is much easier to clean.

Large oedometer

Large oedometer

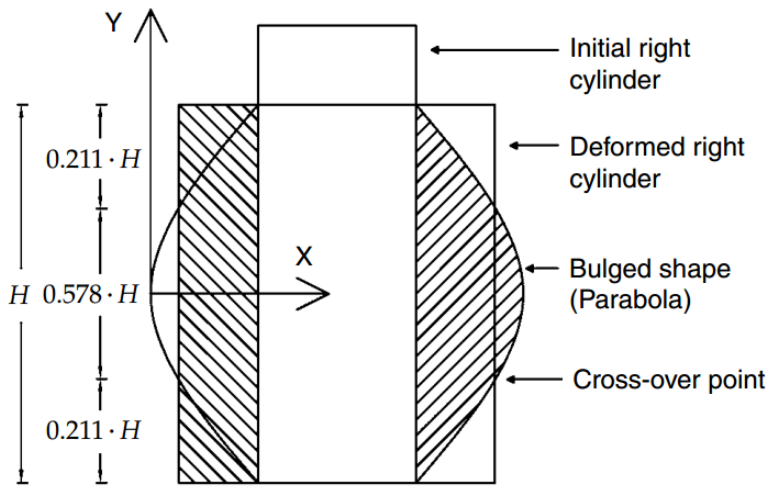


Large oedometer

Triaxial device

H/D RATIO – BULGING (BARRELING) AND BUCKLING

In order to keep the sample strains uniformly distributed as much as possible we need to consider restraint effect due to friction on the end plates (bulging) and to find out the appropriate sample height in order to reduce the risk of buckling – extended load ram – H/D ratio 1:1



Triaxial device

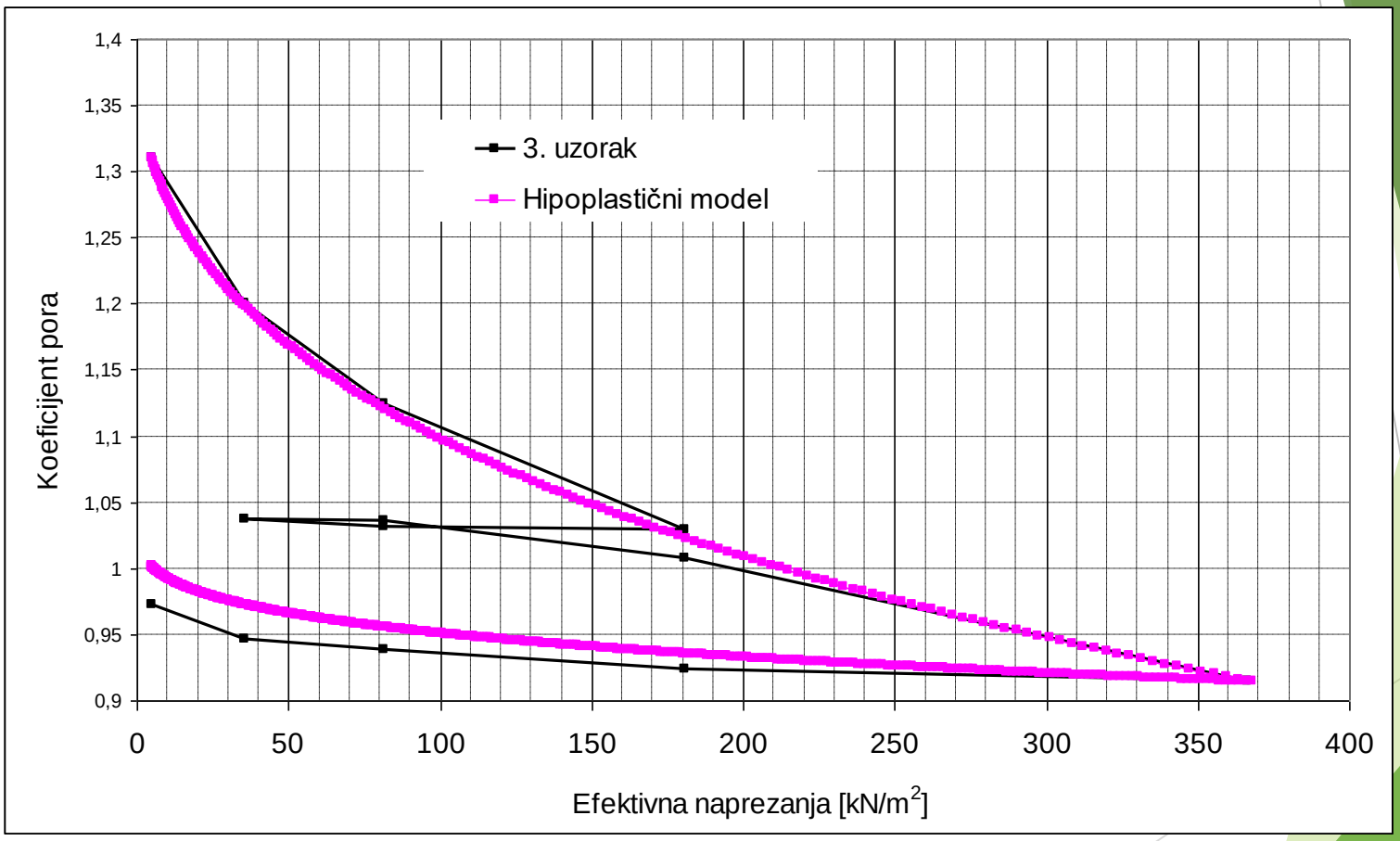
- additional P-V controler for mesurement of hydraulic conductivitiy

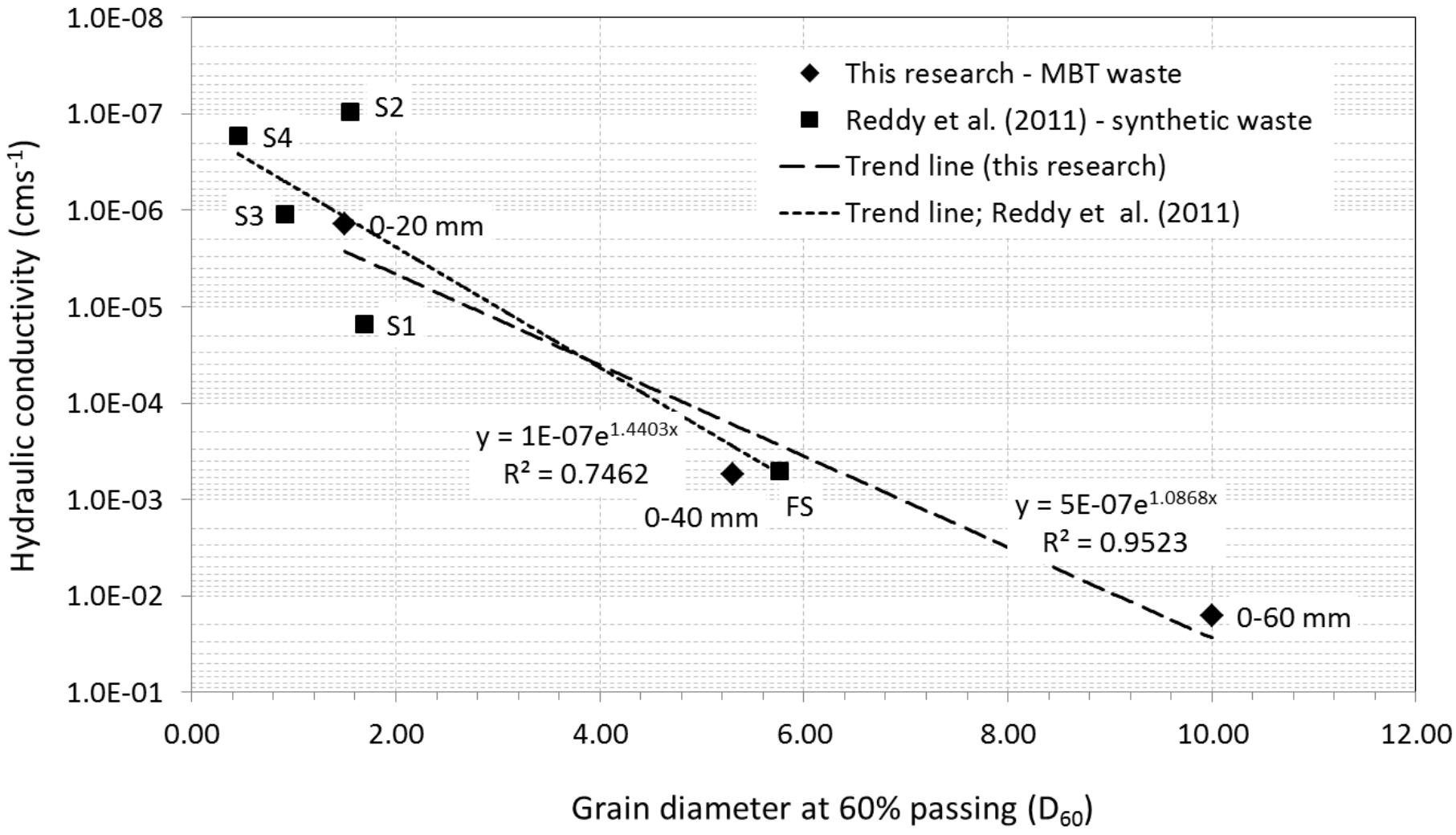
Direct shear test

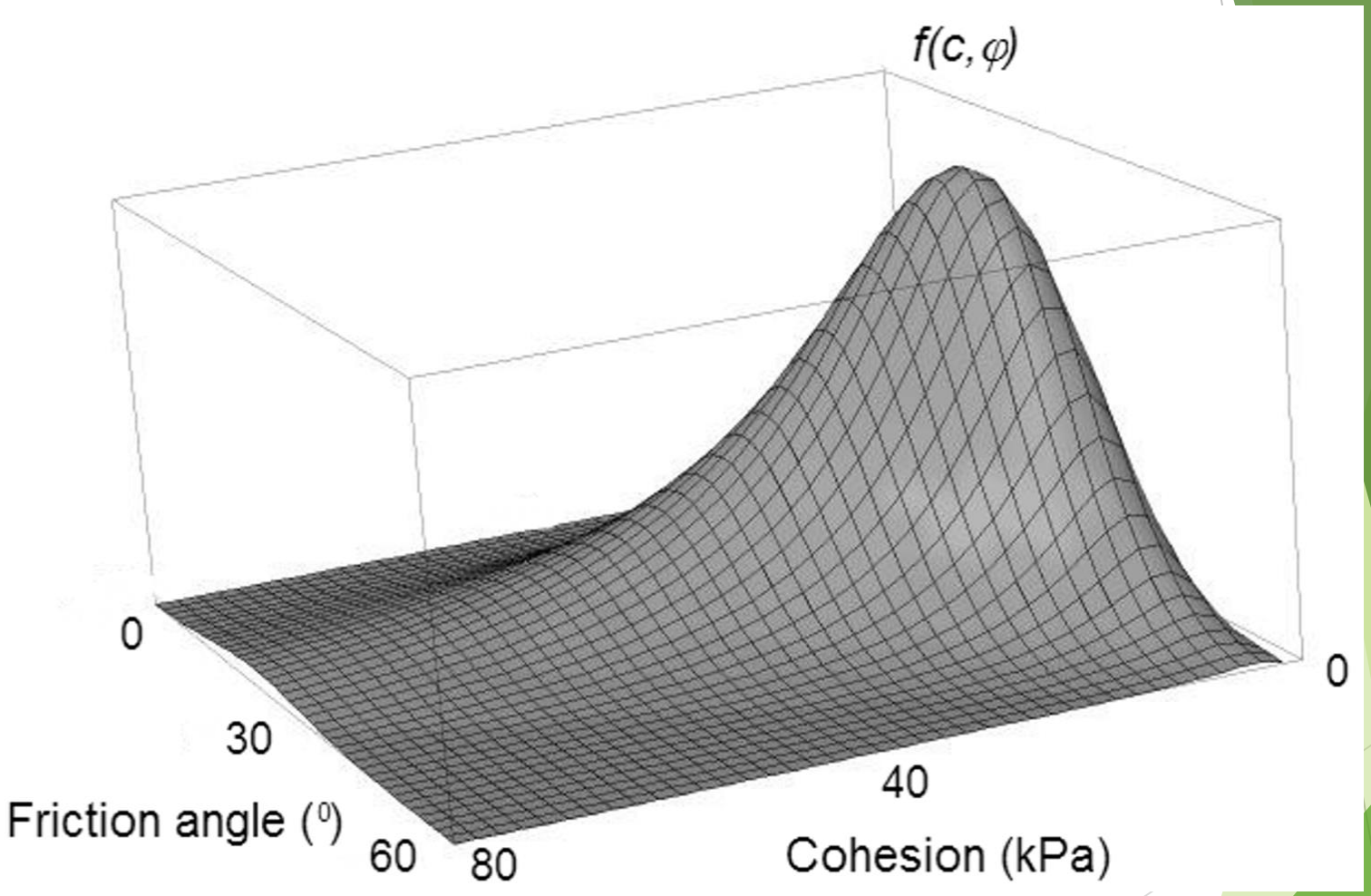
- IGH Zagreb; University Grenoble - France

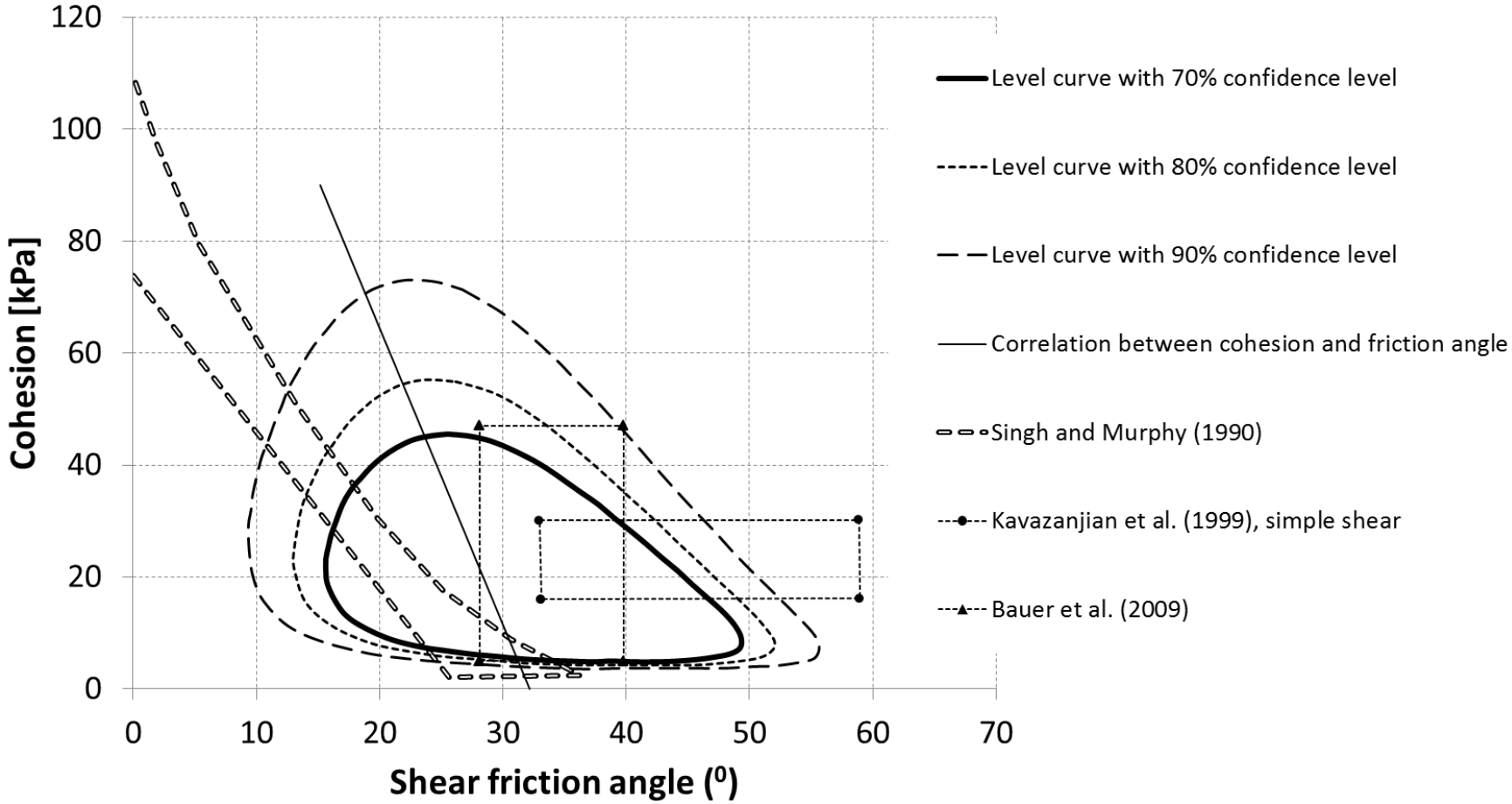
Direct shear test

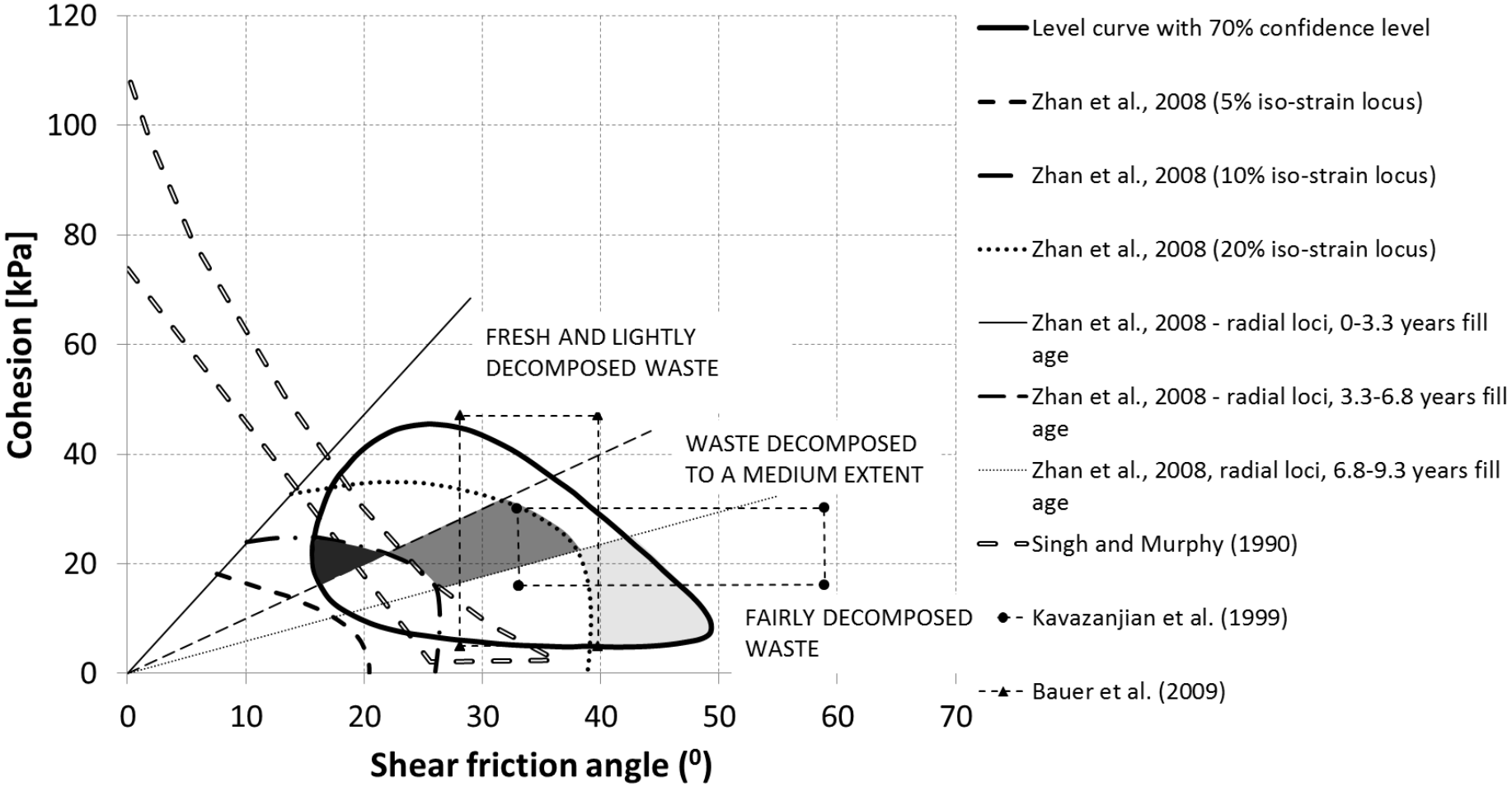
Numerical model




1.0E-08
1.0E-07
1.0E-06
1.0E-05
1.0E-04
1.0E-03
1.0E-02
1.0E-01
Hydraulic conductivity (cms-1)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Grain diameter at 60% passing (D60)
This research - MBT waste
Reddy et al. (2011) - synthetic waste
Trend line (this research)
Trend line; Reddy et al. (2011)
S2
S4
S3
0-20 mm
S1
y = 1E-07e1.4403x
R² = 0.7462
0-40 mm
FS
y = 5E-07e1.0868x
R² = 0.9523
0-60 mm


f(c, φ)
0
30
60
80
Friction angle (⁰)
0
40
Cohesion (kPa)


120
100
80
60
40
20
0
Cohesion [kPa]
0
10
20
30
40
50
60
70
Shear friction angle (⁰)
Level curve with 70% confidence level
Level curve with 80% confidence level
Level curve with 90% confidence level
Correlation between cohesion and friction angle
Singh and Murphy (1990)
Kavazanjian et al. (1999), simple shear
Bauer et al. (2009)


Cohesion [kPa]
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
Shear friction angle (⁰)
FRESH AND LIGHTLY DECOMPOSED WASTE
WASTE DECOMPOSED TO A MEDIUM EXTENT
FAIRLY DECOMPOSED WASTE
Level curve with 70% confidence level
Zhan et al., 2008 (5% iso-strain locus)
Zhan et al., 2008 (10% iso-strain locus)
Zhan et al., 2008 (20% iso-strain locus)
Zhan et al., 2008 - radial loci, 0-3.3 years fill age
Zhan et al., 2008 - radial loci, 3.3-6.8 years fill age
Zhan et al., 2008, radial loci, 6.8-9.3 years fill age
Singh and Murphy (1990)
Kavazanjian et al. (1999)
Bauer et al. (2009)

RDF?

By decreasing the moisture content within the waste mass, and by keeping the degradation of organic waste during the biodrying process to a minimum, the lower heating value of biodried waste increases.

From composting studies, it is evident that at moisture contents below 20% (w/w), very little or no microbiological activity occurs. Therefore, achieving final moisture contents that are significantly lower than 20% (w/w) through biodrying only is unlikely.

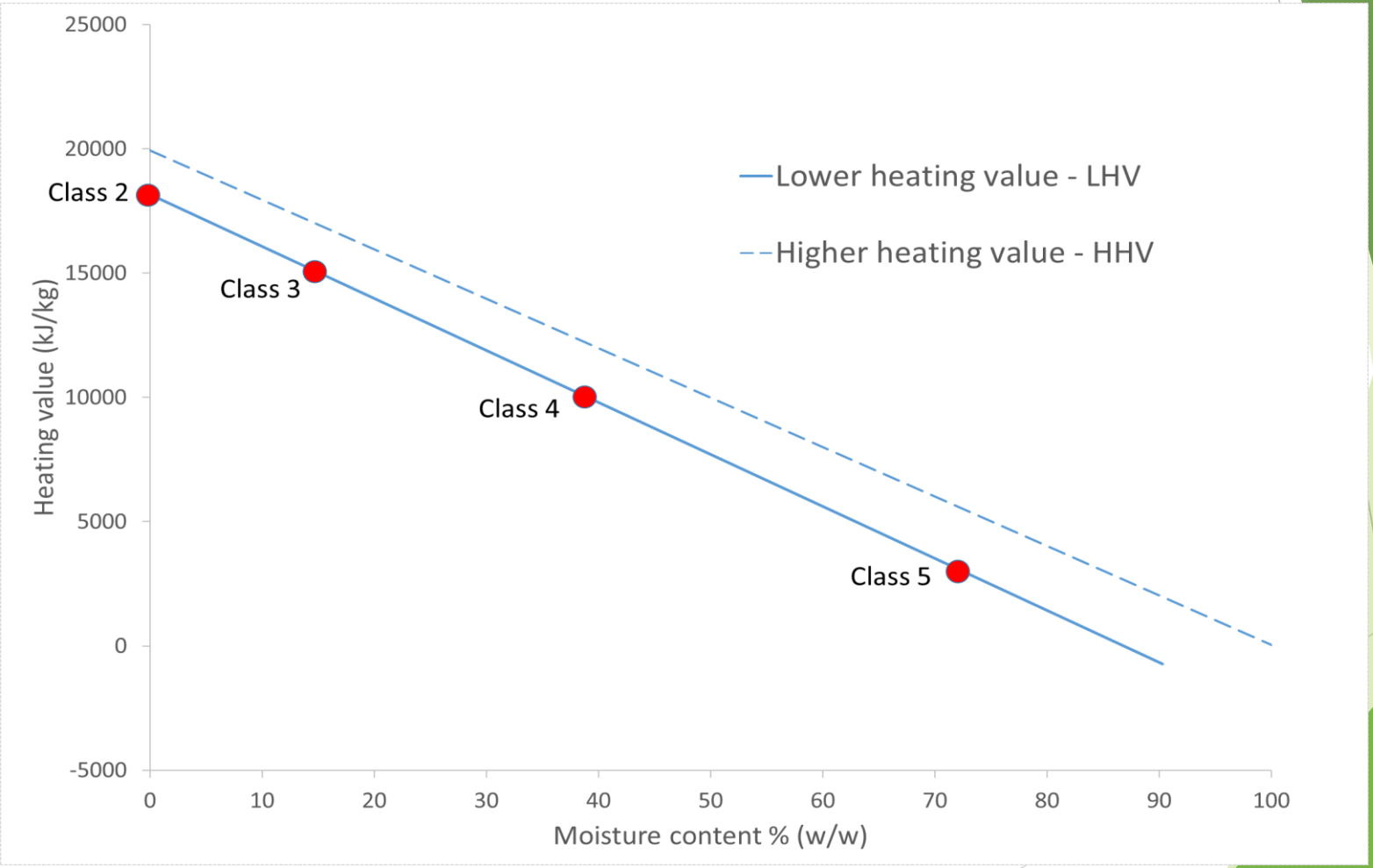
RDF?

The general relationship between calorific value of biomass (lower and higher heating values) and moisture content.

For comparison purposes, lower heating value limits, one of the main RDF classification properties, was also added to.

As can be seen, Class 1 and Class 2 RDFs are almost completely dry fuels. Class 3 RDFs can contain up to 15% moisture content (w/w), Class 4 RDFs can contain up to 39% moisture content (w/w), and Class 5 RDFs can contain up to 73% moisture content (w/w).

RDF?


25000
20000
15000
10000
5000
0
-5000
Heating value (kJ/kg)
0
10
20
30
40
50
60
70
80
90
100
Moisture content % (w/w)
Lower heating value - LHV
Higher heating value - HHV
Class 2
Class 3
Class 4
Class 5

Simulation of byodrin s

Questions?