**Minutes** **104.086**

EFCE Working Party "Mechanics of Particulate Solids": Business Meeting 2004

2004-05-04/du
GCT/T – L 540
Dr. Hermann Feise
Tel 21553

**Meeting on:** 2004-03-15

**Participants**

**see page 2**

**Abstract**

The meeting was held in Nürnberg, Germany on the occasion of the 2004 PARTEC conference.

M. Poletto and P. Canu joined the working party.
The working party will be working on a mission statement to support the recruting of new delegates and the definition of new subjects.
The next business meeting will take place in Glasgow, UK during the 7th World Congress Chemical Engineering.

**Signature**

**Distribution**

Participants
WPMPS-Delegates
WPMPS permanently invited guests
Willi Meyer, Dechema Frankfurt

**Pages/Enclosures** **3/12**

## Participants

| Name | Affiliation | Country |
|---|---|---|
| Hermann Feise | BASF | Germany |
| Paolo Canu | Uni Padova | Italy |
| John Carson | Jenike & Johanson | USA |
| Rolf K. Eckhoff | University of Bergen | Norway |
| Tim Bell | DuPont Co. USA | USA |
| Detlef Höhne | TU Bergakademie Freiberg | Germany |
| Martin Kaldenhoff | HHW & Partner | Germany |
| Marek Molenda | Inst. of Agrophysics | Poland |
| Massimo Poletto | University of Salerno | Italy |
| Jörg Schwedes | TU Braunschweig | Germany |
| Jürgen Tomas | University of Magdeburg | Germany |
| Ugur Tüzün | University of Surrey | United Kingdom |
| Josef Weber | DOW | Germany |
| Harald Wilms | Zeppelin | Germany |
| Gary Liu | DuPont | USA |
| Jiri Zegzulka | TU Ostrava | Czech Republic |
| Dietmar Schulze | FH Braunschweig | Germany |

# Table of Contents

# Minutes

04. May 2004/du
GCT/T – L 540
Dr. Hermann Feise
+49-621-60-2 15 53
+49-621-60-5 24 11
hermann.feise@basf-ag.de

## EFCE WORKING PARTY "MECHANICS OF PARTICULATE SOLIDS": BUSINESS MEETING 2004, 15-MARCH-2004

### Abstract:

The meeting was held in Nürnberg, Germany on the occasion of the 2004 PARTEC conference.
M. Poletto and P. Canu joined the working party.
The working party will be working on a mission statement to support the recruiting of new delegates and the definition of new subjects.
The next business meeting will take place in Glasgow, UK during the 7th World Congress Chemical Engineering.

### Participants:

| Name | Affiliation | Country |
|---|---|---|
| Hermann Feise | BASF | Germany |
| Paolo Canu | Uni Padova | Italy |
| John Carson | Jenike & Johanson | USA |
| Rolf K. Eckhoff | University of Bergen | Norway |
| Tim Bell | DuPont Co. USA | USA |
| Detlef Höhne | TU Bergakademie Freiberg | Germany |
| Martin Kaldenhoff | HHW & Partner | Germany |
| Marek Molenda | Inst. of Agrophysics | Poland |
| Massimo Poletto | University of Salerno | Italy |
| Jörg Schwedes | TU Braunschweig | Germany |
| Jürgen Tomas | University of Magdeburg | Germany |
| Ugur Tüzün | University of Surrey | United Kingdom |
| Josef Weber | DOW | Germany |
| Harald Wilms | Zeppelin | Germany |
| Gary Liu | DuPont | USA |
| Jiri Zegzulka | TU Ostrava | Czech Republic |
| Dietmar Schulze | FH Braunschweig | Germany |

### Distribution:

Participants
WPMPS-delegates
WPMPS permanently invited guests
Willi Meyer, Dechema, Frankfurt

## 1 Place

The 2004 business meeting of the EFCE Working Party on the Mechanics of Particulate Solids (WPMPS) was held at the Nürnberg Messe Center on the occasion of the PARTEC 2004 conference.

## 2 Member Issues

W. Goossens of Belgium has announced his intention to retire from the working party in the near future.

Prof. M. Poletto (U. Salerno) and Prof. P. Canu (U. Padova) have been named Italian delegates to the WPMPS. Both gave an introduction their activities, see enclosures 2 + 3.

## 3 Upcoming Events

2005: The "7th World Congress Chemical Engineering" will take place in Glasgow, Scotland from July 10th – 14th, 2005 organized by the IChemE on behalf of the EFCE.
The call for papers for this conference is expected for April 2004. The deadline for the submission of abstracts will be 1st July 2004. The working party will have its 2005 business meeting during the world congress.

2006: The "5th International Conference for Conveying and Handling of Particulate Solids" (5CHoPS) will take place in Italy in September 2006. The working party intends to meet during 5CHoPS. The exact date for the conference is currently not finalized.

The "World Congress Particle Technology 5" will take place in Orlando, Florida from 22nd to 27th April 2006. The working party will endorse this conference and contact EFCE concerning the use of its logo.

**[Action: Feise]**

2007: PARTEC 2007 will be held at Nürnberg, Germany.
The 5th European Conference Chemical Engineering could run in 2007.

## 4 Reports conc. Standardization Activities

### 4.1 ISO (J. Carson)

The ISO is about to issue a new standard concerning the use of a Jenike shear tester in the characterization of coal. It is referenced as

*ISO 15117-1: Coal Flow Properties – Part one; Bin Flow*

John Carson reports that the standard is full of errors. However, it came to his attention far too late to make any changes. J. Carson recommends therefore to ignore the standard as much as possible.

According to the rules of ISO, revisions will not be possible before 5 years have passed. The panel for ISO 15117-1 was headed by Mr. Sliger of Australia. No members from any "WPMPS-country" ware represented.

### 4.2 ASTM (T. Bell)

The ASTM standards committee D18.24 is still busy writing standards concerning the characterization of bulk solids. Its current subjects include:

- segregation testers
- fluidization / de-aeration testing
- loose and tapped bulk density
- pneumatic conveying

The ASTM committee feels a particular need to standardize fluidization testing. The second focus is on segregation testing. Recently, two methods for segregation testing developed by Jenike & Johanson (J. Carson) have been adopted. Another method developed by the Wolfson Center (M. Bradley) in the QPM project (see WPMPS-Minutes 2003) is being considered. Details on the QPM-Segregation tester can be found at http://qpm.org.uk

While it is permissible to standardize methods for patented devices, it is not encouraged. Standards must describe the device in sufficient detail that someone else could construct it.

The standard does describe the device and its operating procedure. However, it does not show that the device works.

## 4.3 DIN1055 (M. Kaldenhoff)

The German DIN 1055 will be updated to conform with the upcoming Eurocode (see WPMPS-minutes 2003). However, the DIN has selected to translate the draft "M" of the Eurocode EN1991-4 for its new standard which will go into effect this year. The Eurocode has now been developed further. The final draft "R" is now ready for publication, which shall be done in German, English and French later in 2004.

M. Kaldenhoff discussed several key aspects of the Eurocode and the DIN translation (see encl. 4):

- The Eurocode emphasizes the variability of the material parameters.
- The Eurocode considers three categories of silos depending on the complexity of the design problem. For the highest level (category 3) product testing is mandatory. A short list of products and parameters is provided for the lower categories.
- The Eurocode has improved the special loading cases as compared to the 1987 version of DIN 1055. The old DIN gave non-conservative results for some buckling cases (metal silos)
- The considerations for excentric funnel flow have been substantially improved since 2002.
- The tables for category 1 and 2 design do not contain experimentally gathered material parameters. Instead they have been set such that the Eurocode will give stress predictions equal to the 1987 DIN 1055.
- The coefficients of variation listed in the tables are rather small. Setting them to more realistic values, as had been presented by M. Rotter, would have been providing a stronger emphasis for material testing.

## 5 Measurement of the Horizontal Stress Ratio

EN 1991-4 requires the direct measurement of K, the horizontal stress ratio, for class 3 silos. Older standards have always suggested the use of tabulated or approximated values.

H. Feise gave an introduction into the concept of testing for K as described by EN1991-4; see encl. 5. The description of apparatus and procedure is rather short, since EN1991-4 is a design code and not the proper vehicle to standardize testing methods. From the paper by Kwade et al* it follows that many factors do influence the test outcome (e.g. wall friction, filling procedure, stress level…). It is obvious from the paper that a much more concise description of the test method is needed.

* Kwade, A.; Schulze, D.; Schwedes, J.; powder handling and processing, 6(1994)1, 61-65 and 6(1994)2, 199-203

Of the participants only 4 have a tester available to measure the horizontal stress ratio. The testers vary in construction. Whether their results coincide is not known.

D. Höhne is currently preparing a research proposal concerning the measurement of K, which he intends to submit to the Deutsche Forschungsgemeinschaft (DFG) this year. The DFG is the German federal research funding body.

## 6 TP8: Simple Industrial Shear Testing Procedure

The interest group on "simple Powder Testing" has met in Budapest after the meeting. Currently L. Bates is preparing a discussion paper for this subject. M. Bradley is currently trying to solicit funding for the related research project from the British food industry, see encl. 6.

M. Bradley has provided a short report on the status of his activities, see encl. 7.

## 7 Short Courses

The University of Surrey is offering a set of short courses on current subjects like "Biotech", "Process Intensification" and "Nano-Characterization/Manufacture". These modular courses are offered to professionals in industry as well as those who are studying for part or full-time MSc. degrees, see encl. 8. The courses allow master degree education to follow the very fast pace of technology and technological progress. The set of short courses presented by U. Tüzün are accompanied by assignments, industry projects and a proper MSc-Thesis.

## 8 Organisational Matters

### 8.1 7th Worlds Congress of Chemical Engineering (7th WCCE)

The organizers of 7th WCCE are asking for suggestions on topics, workshops, sessions. The conference preparation schedule is given in encl. 9.

The working party suggests two topics:

- Handling of Ultra fine Powders
- The Use of CFD in Powder Handling

*Tim Bell suggested "Silo Structures and Flow" in a post meeting communication, possibly chaired by Jin Ooi.*

**[Action: Feise]**

### 8.2 50th Anniversary of EFCE

During its anniversary meeting in 2003 the EFCE general assembly proposed a series of "state-of-the-art-papers" in the subject areas, see encl. 10.

The working party feels currently not in a position to write such a paper. It should rather discuss its future strategy before attempting such a publication. Issues raised were:

- The WPMPS has so far successively looked at: powder characterization, silo design for flow, silo design for strength.

- The WPMPS was initially united by the common task to develop a shear testing procedure. It has not developed a "new task" since the writing of SSTT.
- Do we need to look for specific topic to work on?
- Do we have the right people for the right job?
- Where is a home for fluidization technologies?
- Should we relax particulate solids into particulate materials or particulate mechanical phenomena?

*After the meeting two comments concerning these subjects were received by the chairman. H. Wilms commented on the benefits of community building, see encl. 11. L. Bates offered his views on the running of technical projects and the in-frequent meetings of the working party.*

## 8.3 Subjects not covered:

The meeting ended without touching on three subjects:

- SSTT in German (Feise)
- Technical Project No. 7: "Terminology" (Bates)
- Powder characterization by Archimedes number (Goossens)

All will be considered during the 2005 meeting.

## 8.4 Next Meeting

The WPMPS will convene during the 7th World Congress of Chemical Engineering.

It will hold its business meeting in close relation to the sessions dealing with bulk solids handling. Since the conference program is not yet detailed, the exact time will have to be defined after July 2004.

**[Action: Feise]**

## Enclosures

1. AGENDA
2. Introduction M. Poletto, I
3. Introduction P. Canu, I
4. EN 1991-4 and IN (M. Kaldenhoff)
5. Measuring the horizontal stress ratio
6. TP8: "Simple Industrial Shear Testing Procedure"
7. DEFRA project (M. Bradley)
8. Short Courses (U. Tüzün)
9. WPMPS at 7WCCE
10. 50th Anniversary of EFCE
11. Comment by H. Wilms (email 23.03.04)
12. Comment by L. Bates (email 24.03.04)

EFCE – Working Party

# Mechanics of Particulate Solids

15 March 2004, 15:00h
Room "Prag" at the Nürnberg Messe Center
Nürnberg, Germany

# AGENDA

| | |
|---|---|
| Items from Budapest 2003 | [Feise] |
| Introduction of new delegates | |
| Prof. M. Poletto, U Salerno | [Paletto] |
| Canu, U Padova | [Canu] |
| Standards | |
| ISO code on shear testing | [Carson] |
| ASTM - Standards Activities | [Bell] |
| Eurocode with special view to DIN | [Kaldenhoff] |
| Short Courses: | [Tüzün] |
| - Biotech: Cells as Particles | |
| - Process Intensification | |
| - Nano-Charcaterization / Manufacture | |
| Reports from Technical Projects: | |
| No7: "Terminology" | [Bates] |
| No8: "Simple ...Test Procedure" | [Bates, Bradley] |
| Workshops / Sessions at 7th World Congress Chemical Engineering | [Feise] |
| Measuring the horizontal stress ratio | [Feise] |
| SSTT – Translation into German | [Feise] |
| Date and Place of next meeting(s) | [Feise] |

# Introduction and Research Activity

Prof. Paolo Canu

*Chem. Eng. - Plants and Processes Dept. (DIPIC)*
*University of Padua – Italy*

March 15th, 2004 – Nurnberg (Partec 2004)

# Education

| | |
|---|---|
| *1986* | *M.Sc. – Chem. Eng, (Milan, Politecnico)* |
| *1990* | *Ph. D. – Chemistry, (Normale, Pisa; Madison, WI)* |
| *1992* | *Process Engineer, (Actea, Bergamo)* |
| *1994* | *Lecturer, (Padua, Chem. Eng.)* |
| *1998* | *Professor, (Padua, Chem. Eng)* |

***Background**:*

*Chem. Reaction Eng.*
*Fluid Mechanics*
*Mathematical and Numerical Modelling*

# Context

*University of Padua*

*Large public university (approx. 70.000 students)*
*Veneto, Italy, North-East (approx. 30km from Venice)*
*Lots of industries in the area (mostly SME)*

*Chem. Eng. - Plants and Processes Dept. (DIPIC)*

*Historical Chem. Eng. Dept.*
*Small Dept.*
*Quite good structures (laboratories, workshops, personnel,..)*

# Coworkers

*2 post-docs (Santomaso & Strumendo)*
*2 Ph.D. students*
*Several (4 to 10) 'master' students*

# Funding

*Public (MIUR, UniPd)*

*Pharma*
*Food*
*Cement*
*Fertilizers*
*Detergents*
*Metallic powders*

# Research

## hystorical perspective (1/2)

Themes:

*Mixing (1997-)*

**?**

*Flowability*

**?**

*Fundamentals of particles interactions (dense and diluted)*

# Research

## hystorical perspective (2/2)

Approaches:

*Modelling*

***?***

***Experiments*** *+ Modelling*

*(Development of original experimental techniques)*

# Research

## Consolidated results (1/2)

| | |
|---|---|
| Onset of flow in inclined chutes and reological model of the frictional layer | Chem. Eng. Sci., 56 (11), 3563-3573 (2001) |
| Method of moments for the dilute granular flow of inelastic spheres and application to rapid, free-surface flow down chutes | Physical Review E, 66, 041304, 1-20 (2002) |
| Revision of the HR flowability index, introduction of a novel ratio based on a different method to determine high packing conditions | Chem. Eng. Sci., 58 (13), 2857-2874 (2003)<br>PARTEC 2004 |
| Transient composition patterns in tumbler mixers (rolling regime) – measurements and interpretation | PARTEC 2001<br>Chem. Eng. Sci. (2003), in review |
| Kinetics of mixing in tumblers (rolling and cataracting regimes) | Powder Tech., submitting |

# Research

## Consolidated results (2/2)

| | |
|---|---|
| Simulation of PSD dynamics in grinding processes through a collection of analytical Particle Size Sub-Distributions | PARTEC 2004 |
| Online PsizeD & PshapeD measurements (optical, through continuous image analysis on process streams) | Unpublished, Industrial testing |
| A novel probe for industrial sampling of powders | Unpublished, patenting? |
| Method of moments for gas-solid flows: application to the riser in CFB | Unpublished Fluidization XI |

# Research

## Ongoing projects

1. Vertical convection of granular material through vibration
2. Simulation of pipe-flow driven by gravity through CFD & semiempirical constitutive laws
3. Measurements of particles velocity profiles and fluctuations in rapid flows
4. Role of particle size on calibration curves for composition measurements by image analysis
5. Improvements upon the empirical correlations of discharge flow, under aerated (upward and downward) conditions
6. CFD modelling of powder mixing
7. Critical review of repose angle measurement procedure for cohesive powders
8. Measurements of local velocity and voidage degree by laser/optical fibres.
9. Critical analysis of breakage functions; formulation and testing of novel functions
10. Prediction of colloidal particles deposition on surfaces: the role of diffusion in a DLVO approach

# Summary

Mixing
Flow structure
Experimental techniques
Modelling

# Closure

I expect to learn
from experienced collegues in this WP,
through stimulating discussions
and successful cooperations

## DIN 1055 Teil 6 / EuroCode 1 Part 4 / EN 1991-4

Short presentation / Short overview

M. Kaldenhoff
WPMPS, Nürnberg, March 2004



## DIN / EuroCode

| | |
|---|---|
| DIN 1055 Part 6 (1964): | Lastannahmen auf Bauten<br>Lasten in Silozellen |
| DIN 1055 Part 6 (1987): | Lastannahmen auf Bauten<br>Lasten in Silozellen[1)] |
| EuroCode 1 (2004): | Actions on structures |
| Part 4: | Silos and tanks |

[1)] In force until now

## Failure / Damage

Dr. Kaldenhoff, Braunschweig

WPMPS, Nürnberg, März 2004

## DIN / EuroCode (EC) Development Timetable

| DIN | |
|---|---|
| 1964 | DIN 1055 P6<br>Prof. Pieper |
| | |
| 1987 | DIN 1055 P6<br>New Version |
| | |
| 1996-2000 | EDIN 1055 P6<br>different drafts |
| 12/2003 | EDIN 1055 P6<br>last draft |
| 02/2004 | EDIN 1055 P6<br>time-limit for comments |

| Eurocode | |
|---|---|
| ~1970 | Start of Eurocode-System |
| 1986 | M. Rotter, 1st publish problem of funnel-flow |
| ~1990 | EC1 P4<br>First Draft |
| 2003 | EC1 P4<br>Draft M |
| 02/2004 | EC1 P4<br>Draft R, final final final |

Dr. Kaldenhoff, Braunschweig

WPMPS, Nürnberg, März 2004

## Generell structure / contents of DIN / EC

- Representation and classification of actions
- Design situations
- Properties of particulate solids
- Loads on the vertical wall on silos
- Loads on silos hoppers and silos bottom
- Loads on tanks from liquids

EC: 108 pages

DIN: 12 pages

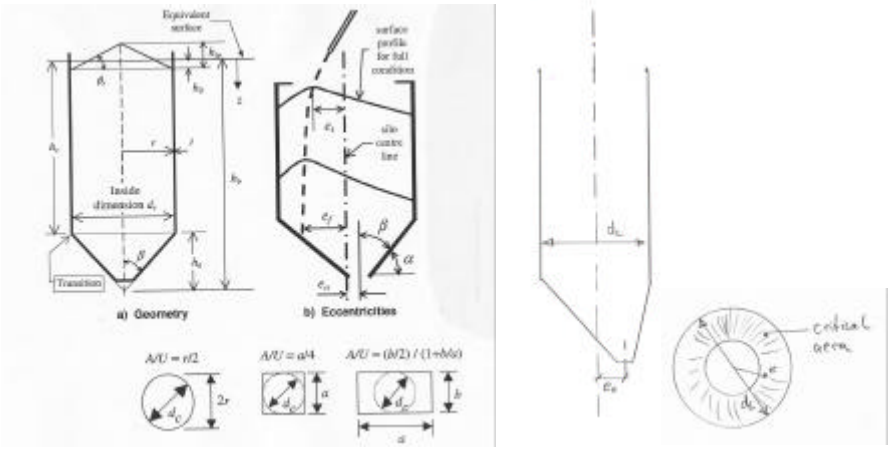


## Representation and classification of actions

| **Action Assessment Class** | **Description** |
|---|---|
| Action Assessment Class 1 | Silos with capacity below 100 tonnes |
| Action Assessment Class 2 | All silos coverd by this standard and not placed in another class |
| Action Assessment Class 3 | Silos with capacity in excess of 10.000 tonnes<br>Silos with capacity in excess of 1.000 tonnes in which any of the following design situation occur:<br><br>a) eccentric discharge with $e_o/d_c > 0,25$<br><br>b) Squat silos with top surface eccentricity with $e_t/d_c > 0,25$ |

HHW+Partner

## Silo forms showing dimensions






HHW+Partner

## Properties of particulate solids

**Table E1 - Particulate solids properties †**

| Type of particulate solid | Unit weight $\gamma$ | | Angle of repose $\varphi_r$ | Angle of internal friction $\varphi_i$ | | Lateral pressure ratio $\kappa$ | | Wall friction coefficient ‡ $\mu$ ($\mu$ = tan $\varphi_w$) | | | | Patch load safety reference factor $C_{pa}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma_c$ | $\gamma_k$ | | $\varphi_{im}$ | $a_f$ | $\kappa_m$ | $a_\kappa$ | Wall type D1 | Wall type D2 | Wall type D3 | $a_\mu$ | |
| | Lower value kN/m³ | Upper value kN/m³ | degrees | Mean degrees | Factor | Mean | Factor | Mean | Mean | Mean | Factor | |
| Default material † | 8.0 | 20.0 | 40 | 36 | 1.3 | 0.56 | 1.5 | 0.32 | 0.38 | 0.80 | 1.48 | 1.0 |
| Aggregates | 17.5 | 18.5 | 35 | 31 | 1.10 | 0.52 | 1.15 | 0.39 | 0.49 | 0.89 | 1.12 | 0.4 |
| Alumina | 16.0 | 17.0 | 30 | 26 | 1.20 | 0.54 | 1.20 | 0.41 | 0.50 | 0.91 | 1.07 | 0.5 |
| Animal feed etc. | 8.0 | 9.0 | 38 | 28 | 1.08 | 0.46 | 1.10 | 0.32 | 0.30 | 0.40 | 1.20 | 1.0 |
| Animal feed pellets | 8.0 | 9.0 | 37 | 25 | 1.06 | 0.47 | 1.07 | 0.29 | 0.20 | 0.37 | 1.20 | 0.7 |
| Barley ⊘ | 7.0 | 8.0 | 31 | 26 | 1.14 | 0.50 | 1.15 | 0.34 | 0.33 | 0.46 | 1.16 | 0.6 |
| Cement | 13.5 | 16.0 | 45 | 32 | 1.20 | 0.54 | 1.20 | 0.41 | 0.46 | 0.81 | 1.07 | 0.5 |
| Cement clinker † | 15.0 | 18.0 | 37 | 40 | 1.20 | 0.38 | 1.31 | 0.48 | 0.60 | 0.82 | 1.07 | 0.7 |
| Coal ⊘ | 7.0 | 12.0 | 38 | 31 | 1.15 | 0.52 | 1.15 | 0.43 | 0.48 | 0.85 | 1.12 | 0.6 |
| Coal, powdered ⊘ | 6.0 | 8.0 | 34 | 27 | 1.26 | 0.55 | 1.20 | 0.41 | 0.51 | 0.89 | 1.07 | 0.5 |
| Coke | 8.5 | 8.5 | 38 | 31 | 1.15 | 0.52 | 1.15 | 0.49 | 0.54 | 0.89 | 1.12 | 0.6 |
| Glass ‡ | 8.0 | 15.0 | 41 | 35 | 1.15 | 0.46 | 1.20 | 0.52 | 0.62 | 0.76 | 1.07 | 0.5 |
| Meal ⊘ | 6.0 | 7.0 | 45 | 40 | 1.06 | 0.50 | 1.10 | 0.54 | 0.53 | 0.49 | 1.20 | 0.5 |
| Iron ore pellets | 19.0 | 20.0 | 30 | 31 | 1.15 | 0.52 | 1.15 | 0.49 | 0.56 | 0.89 | 1.12 | 0.6 |
| Lime, hydrated | 6.0 | 8.0 | 34 | 27 | 1.26 | 0.55 | 1.20 | 0.39 | 0.41 | 0.81 | 1.07 | 0.6 |
| Limestone powder | 11.0 | 13.0 | 36 | 30 | 1.20 | 0.54 | 1.20 | 0.41 | 0.51 | 0.89 | 1.07 | 0.5 |
| Maize ⊘ | 7.0 | 8.0 | 30 | 31 | 1.14 | 0.52 | 1.14 | 0.33 | 0.39 | 0.53 | 1.04 | 0.9 |
| Phosphate | 19.0 | 22.0 | 34 | 29 | 1.10 | 0.50 | 1.15 | 0.53 | 0.49 | 0.54 | 1.12 | 0.5 |
| Potatoes | 6.0 | 8.0 | 34 | 30 | 1.12 | 0.54 | 1.15 | 0.33 | 0.56 | 0.48 | 1.05 | 0.5 |
| Sand | 14.0 | 16.0 | 30 | 35 | 1.08 | 0.45 | 1.11 | 0.58 | 0.48 | 0.87 | 1.16 | 0.6 |
| Slag cement | 10.5 | 12.0 | 40 | 36 | 1.08 | 0.45 | 1.11 | 0.48 | 0.57 | 0.87 | 1.16 | 0.6 |
| Soya beans | 7.0 | 8.0 | 29 | 25 | 1.16 | 0.60 | 1.15 | 0.39 | 0.39 | 0.49 | 1.16 | 0.5 |
| Sugar ⊠ | 8.0 | 9.5 | 39 | 30 | 1.13 | 0.50 | 1.20 | 0.46 | 0.51 | 0.89 | 1.07 | 0.4 |
| Sugar beet pellets | 6.5 | 7.5 | 39 | 31 | 1.15 | 0.52 | 1.15 | 0.56 | 0.44 | 0.84 | 1.12 | 0.5 |
| Wheat ⊘ | 7.5 | 8.5 | 34 | 30 | 1.12 | 0.54 | 1.15 | 0.34 | 0.38 | 0.57 | 1.16 | 0.5 |

† Where this table does not contain the material to be stored, testing should be undertaken.
For situations where it is difficult to justify the cost of testing, because the cost implications of using a wide property range for the design are minor, the properties of the "default material" may be used. For small installations, these properties may be adequate. However, they will lead to very uneconomic designs for large silos, and testing should always be preferred.
‡ Effective wall friction for wall Type D4 (corrugated wall) may be found using the method defined in Annex D3.
⊘ Solids in this table that are known to be susceptible to dust explosion are identified by the symbol ⊘
⊠ Solids that are susceptible to mechanical interlocking are identified by the symbol ⊠
NOTE: The unit weight of the solid $\gamma_c$ is the upper characteristic value, to be used for all calculations of actions. The lower characteristic value $\gamma_k$ is provided in Table E1 to assist in estimating the required volume of a silo that will have a defined capacity.

Upper characteristic value of $K = K_m\, a_K$

Lower characteristic value of $K = K_m / a_K$

Upper characteristic value of $m = m_m\, a_m$

Lower characteristic value of $m = m_m / a_m$

Upper characteristic value of $f_i = f_{im}\, a_f$

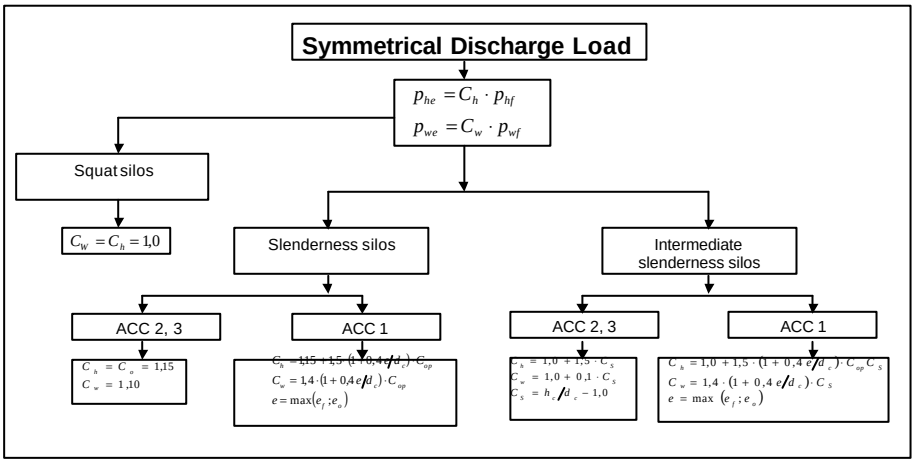
Lower characteristic value of $f_i = f_{im} / a_f$

## Loads on the vertical wall on silos

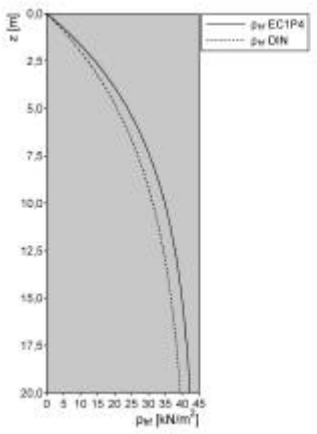
- Symmetrical / Non-symmetrical loads
- Filling loads / Discharge loads
- Slender / intermediate / squat silos ...
- Assessment classes

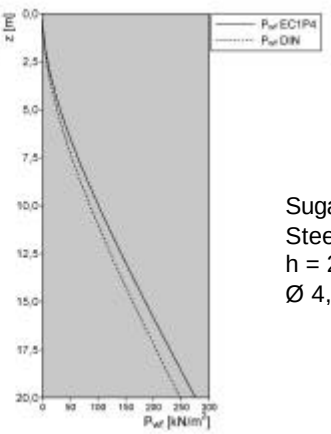


## Loads on the vertical wall on silos



## Typically symmetrical load



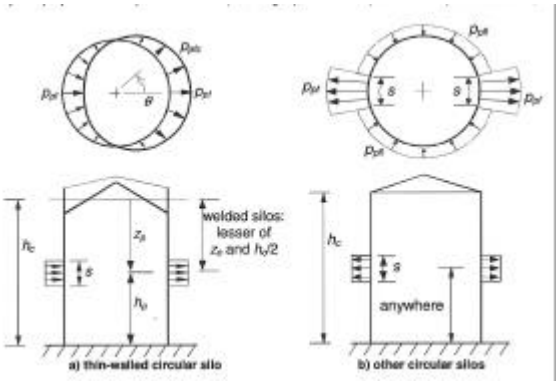




Sugar
Steel
h = 20m
Ø 4,00 m

Dr. Kaldenhoff, Braunschweig

WPMPS, Nürnberg, März 2004

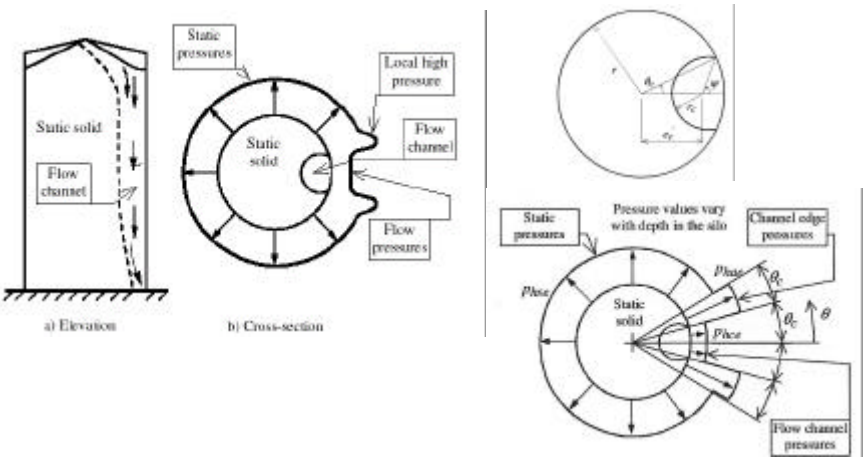
## Patch-Load




Dr. Kaldenhoff, Braunschweig

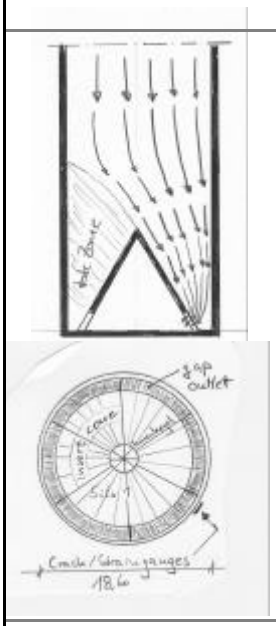
WPMPS, Nürnberg, März 2004

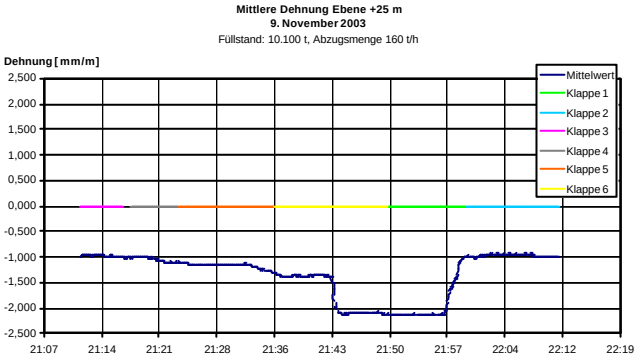
## Funnelflow






## Measurement of funnelflow



HHW + Partner

# DIN 1055 Teil 6 / EuroCode 1 Part 4 / EN 1991-4

Short presentation / Short overview

M. Kaldenhoff
WPMPS, Nürnberg, March 2004

**Process Engineering**

## Measuring the horizontal stress ratio
**(1)**

- EN 1991 – 4 recommends the direct measurement of the horizontal stress ratio K or λ
- Older standards (e.g. DIN 1055 part 6) have suggested to use approximations

(DIN)

$$l = 1.2 \cdot (1 - \sin j)$$

(Kezdi)

$$l = (1 - \sin j)$$

(Koenen)

$$l = \frac{1 - \sin j}{1 + \sin j}$$

Source: Kwade et al. php 2/94

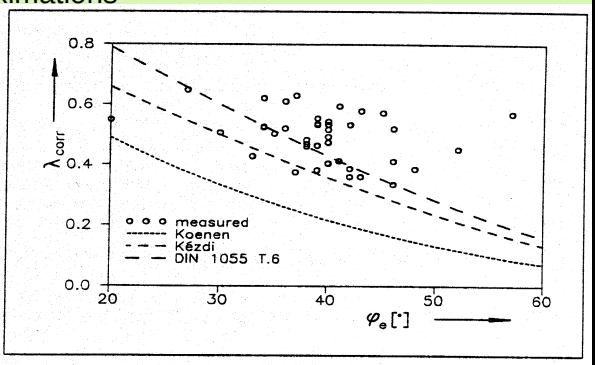



Fig. 8: Stress ratio $\lambda_{corr}$ versus the effective angle of internal friction, $\varphi_e$ (measurements and recommendations)

**Process Engineering**

## Measuring the horizontal stress ratio
**(2)**

- Description of measurement procedure in EN 1991-4 is extremely short, since its not core subject

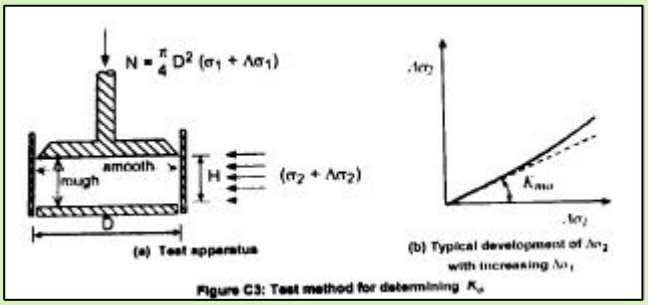



Figure C3: Test method for determining $K_o$

- Is this good enough ???

Process Engineering

## Measuring the horizontal stress ratio
(3)

- Factors influencing the measurement
  - Wall friction
  - Filling procedure (no twisting!!!)
  - Vertical stress level
  - Wall stiffness or flexibility
  - Wall movement due to temperature and humidity changes
- Questions
  - Correction procedures
  - Required measurements (top, bottom, side …)
  - Stress sensors (thin wall, patch …)

Process Engineering

## TP 8: “Simple … Test Procedure

provided by M. Bradley, Wolfson Centre

BASF
The Chemical Company

- Interest Group on “Simple Powder Testing” met in Budapest (Bates, Bell, Bradley, Carson, Enstad, Feise, Schwedes)
- The best “simple” test for cohesive strength is a proper shear tester. However, this requires access to such a tester, which many people have not and will not have.
- In the long run the working party should issue a “roadmap” for indicative testing at the beginning of an engineering project.
- Wolfson Centre is currently setting up a project with the DEFRA in the UK to investigate “Simple Powder Testing” (see M.Bradley’s letter)

Hermann:

I would appreciate it if you would record my apologies for absence from the WPMPS meeting, it is a packed week for me with meetings I cannot escape from.

Nevertheless I would be grateful if you could read out the following statement on my behalf regarding the "Simple powder tester" project:

To the Working Party:

After the last WPMPS meeting we had a meeting of the interest group in "simple powder testing", which we acknowledged to be a bad name but for an important idea. I indicated that we had already given the idea a lot of consideration at The Wolfson Centre and had long been convinced of the need to take this forward. I indicated that I had already done a bit of work to investigate the possibility of obtaining funding for work on this, and would be taking this forward following the encouraging interest shown then.

A few weeks ago I wrote to the other members of the group, via Hermann, to indicate that I had had some success although I could not say too much about the specifics at the time because I had to exercise sensitivity to the interests of the companies I have been working with to obtain resources.

The current position is that we have obtained a promise of funds from the UK government's Department of Environment, Food and Rural Affairs (DEFRA) to pursue this work. In order to obtain the funds from this source, we have had to make our focus the food industry, however I do not see that this materially compromises the usefulness of the work. We all know the problems inherent in solids flow from vessels are highly generic across a wide range of industries. Also the focus has had to be on UK process companies, or multinationals with a substantial UK operation. Links to the "chemical industry" are not counted as contributing towards the project, which is why we have not asked EFCE for any official support given the limited time to do the legwork to get the project set up. Note that we have not used the name of EFCE in any request for support.

Officially we began work at the beginning of March although we have not yet had our first project meeting with all the industrial collaborators present, so the full collaboration contracts and IPR agreement are not yet in place. Consequently, I am not at liberty to say much more until that is complete in the next four weeks or so. However I can reveal that the aim for this year of the project, is to study hopper and silo discharge problems in the food industry to obtain a closer definition of precisely the problem we are trying to solve.

I have made the collaborators and sponsors aware of the interest of the EFCE Working Party in the matter. I hope that once IPR issues are settled, we can open a meaningful dialogue. To that end I would be grateful if the working party, and particularly the sub-group, would consider the possibility of taking an active interest in the project if the industrial sponsors are willing to accept this.

I am sorry that the timing has worked out such that we can't be more specific in planning our collaboration at this meeting, however I hope things will move forward well in advance of the next full meeting of the Working Party. To enable this I am assuming I will be liaising directly with the sub-group to speed things along.

Please accept my compliments and allow me to wish you all a successful event in Nurnberg, and I hope to see you all at the next meeting.

Mike Bradley
The Wolfson Centre for Bulk Solids Handling Technology, University of Greenwich, London UK.

**Process Engineering**

## WPMPS at the 7th World Congress of Chemical Engineering

- WPMPS will meet at 7th WCCE in Glasgow
- Organizers ask for proposals on sessions, workshops …
  - Business meeting
  - Sessions: Characterizing powders for numerical modeling
  - Workshop: Eurocode EN 1991-4
  - ???
- Papers
  - call for papers is expected for April 2004.
  - Call for Papers Closing Date for Abstracts 1 July 2004
  - Paper Submissions December 2004
  - Confirmation of Accepted Contributions March 2005
  - 7th World Congress of Chemical Engineering 10-14 July 2005

**Process Engineering**

## 50th Anniversary of EFCE

BASF
The Chemical Company


- General assembly of EFCE proposed to publish a series of articles on the occasion of the 50th anniversary of the EFCE (founded in 1953)
  - EFCE official journal: “Chemical Engineering Research and Design” (ChERD), Parts A, B & C
  - Scientific paper; 3-6 pages (“review paper”)
  - Outline the development, state of the art, future of the **scientific field** of the working party
  - Dedicated issue for WPMPS?
- ChERD also publishes “news from the working parties”
  - Report on latest WPMPS meeting
  - Call for support (e.g. Session at 7th WCCE)

**Harald Wilms <H.Wilms@zeppelin-zst.de>**

23.03.2004 09:29
Bitte antworten an
"H.Wilms@zeppelin-zst.de"

An: '"hermann.feise@basf-ag.de"' <hermann.feise@basf-ag.de>
Kopie:
Thema: WPMPS

Hallo Hermann,
im nachhinein zu unserer WPMPS-Besprechung in Nürnberg habe ich noch 2 Anmerkungen:

Es war schade, daß es nicht am Abend noch ein gemeinsames Abendessen gegeben hat/geben konnte. Das plötzliche Auseinanderlaufen nach der Besprechung hat eigentlich das wichtigste unserer Arbetisgruppe verhindert: den persönlichen Gedankenaustausch unn die Diskussion tête-a-tête. Außerdem muß natürlich ein sponsor her, früher hat sich dazu die Dechema bereit erklärt, solange es im Rahmen blieb. sonst müssen ein paar Industrieveertreter zusammen schmeissen....

Der andere Punkt ist noch, daß John Carson und ich unseren Vortrag von der Partec von vor 3
Jahren über die Scherversuche in der WPMPS, bei BCR und dann daraus SSTT und ASTM veröffentlichen wollen - natürlich unter Hinweis auf die working party. Ich hatte im Vorfeld des Vortrages in LAX 2000 Novosad informiert.
Eigentlich ist publicity ja etwas, was die working party braucht. Deshalb glaube ich nicht, daß es einen Einwand geben kann. Trotzdem auf jeden Fall die Frage
die Mitteilung an dich und evtl. kannst du dies ja noch als post meeting note aufnehmen.
Viele Grüße
Harald

**"Ajax Equipment"**
**<sales@ajax.co.uk>**

24.03.2004 15:45

An: <hermann.feise@basf-ag.de>
Kopie:
Thema: WPMPS

**Dear Hermann,**

I write again to express regret at being unable to attend the recent Working Party meeting. However, my non-attendance did cause me to reflect in the activities of the group and how best I can constructively support your position as Chairman. The fact that we meet only once a year and that the activities are not funded means that any output is totally dependent upon the goodwill of those members that are prepared to further the objectives and tasks undertaken in their own time and at own expense. It is natural that some members will have their own interests and agenda, such as seeking work that can be supported by grants. My view is that the organisation is an authoritative body that may usefully co-ordinate work in the technology and serve both academia and industry with guidance. This status appears to be under-utilised.

In the past, the group has produced invaluable achievements, including the development of a standard shear cell technique, making available a standard test powder and shown the need for a similar reconciliation procedure for wall friction testing. It also provided a stimulus for me to produce a book on Segregation and to work on producing a list of Terms in the Technology. In general I have to say that progress on all these activities tends to be very slow, mainly for the reasons above. My conclusion is that I think it is necessary to collate small working parties of 3 or 4 persons with common interest, who are willing to undertake well defined and focussed tasks that have specific objectives and deadlines. The group should report to you quarterly to ensure that the agreed program is maintained and then a presentation made at the following annual meeting.

There are many tasks that I see fitting within the above criteria. The one I headed, of investigating a 'simple' method of powder testing, proved somewhat controversial. One important reason seemed to be that the framework of introducing the industrial demand for a basic bulk solid evaluation procedure was not properly established. Whether called 'characterisation', classification', 'defining', 'specifying' or 'evaluating', my experience indicates that there is a wide need for a clearer identification of significant bulk properties in relation to contracts, project and equipment performance evaluation and process guarantees. Some years ago, I prepared a document that was published by The Institution of Mechanical Engineers entitled – 'Guide to the specification of Bulk Solids for Storage and Handling applications'. This was not widely promoted for use as a basis for contracts and therefore made no lasting impression on the Industry. I regularly come across examples of inadequate plant performance because the bounds of the crucial design parameters have not been specified. Disputes that arise between suppliers and users could often be avoided at the onset if some simple measurements been quantified and agreed as tolerable limits with in the contract terms.

It also happens that I am an advisor to The British Materials Handling Board. This organisation was initially set up by the UK Government but is now an independent non-profit making body mainly serving the Solids Handling Industry, which it has identified as most needing education and technological exploitation. Guide documents under consideration are the preparation of a 'Project Flow Audit', identify sensitive region on the flow route through a plant at the design stage, and a 'Guide to the specification of Bulk Solids for Storage and Handling Contracts'. The latter would set out what information is relevant to securing reliable performance and suggestions as to who should provide the data.

If you agree that either of these subjects to be appropriate activities for the WPMPS to co-operate in, I believe that a useful European publication could be produced as a joint document. If industry found these an aid to improving performance, there should be every prospect for them to be adopted internationally, with appropriate acknowledgement to the Working Party. I believe that the benefits to industry could be immense. Your views on all these comments would be appreciated.

**Lyn Bates**