PIARC International Seminar

The Best Practices for Earthworks and Rural Roads

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Special features regarding the testing of processed mineral construction waste and industrial by-products in earthworks

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Overview

1) Background
   - sustainable use of materials in earthworks
   - secondary materials from processed mineral construction waste and industrial by-products
   - compaction in earthworks – purpose, requirements and compaction control

2) Compaction control of secondary materials
   - possible test methods
   - field tests conducted
   - results of direct testing methods and relationship testing methods

3) Conclusion

Background

Sustainable use of materials in earthworks – why?

→ primary building materials (gravel, sand) already exhausted in large parts of the world today

→ limited dumping areas for „real“ waste

→ savings in costs and emissions (e.g. CO_2, noise) through local re-use of mineral building materials

→ legal obligation to reuse mineral residual masses (e.g. in Germany)

→ …

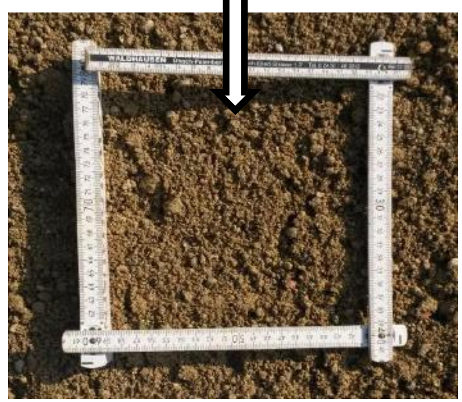
→ application of mineral residual masses as building materials in earthworks is a working focus of TUM ZG

Background

fine-grained and soft soils

soils with high organic content

fine-grained, soft soils „mixed“ with recycled materials



recycled materials

industrial by-products

Background

recycled materials from processed mineral construction waste

selective deconstruction of buildings and roads

collection of the material fractions by type as far as possible

accumulation mainly in the form of broken concrete and building waste mix (bricks, lightweight concrete, mortar, sand-lime bricks,...)

Bodenaufbereitungsanlage
(Quelle: Durmin GmbH)

preparation in building material preparation plants (sorting – crushing – sieving)

aufbereitete Körnungen aus RC-Material

granular bulk materials in different grain sizes for use in earthworks

Background

industrial by-products (e.g. electric furnace oven slag)

electric furnace oven slag:
industrial by-product from steel production in the electric furnace oven

Background

„Substitution von natürlichen mineralischen Baustoffen durch Ersatzbaustoffe im Erd- und Tiefbau“

carried out by „Chair of Soil Mechanics and Foundation Engineering, Rock Mechanics and Tunneling“ (Technical University of Munich)

Zentrum Geotechnik

TUM

funded by „Bavarian Research Foundation“

Bayerische Forschungsstiftung

in cooperation with our industry partners

DURMIN ENTSORGUNG UND LOGISTIK GMBH

Ettengruber .. fair - mit Blick fürs Ganze

FBR FRANKEN RECYCLING

HAMM

MAU Max Aicher Umwelt

STRABAG

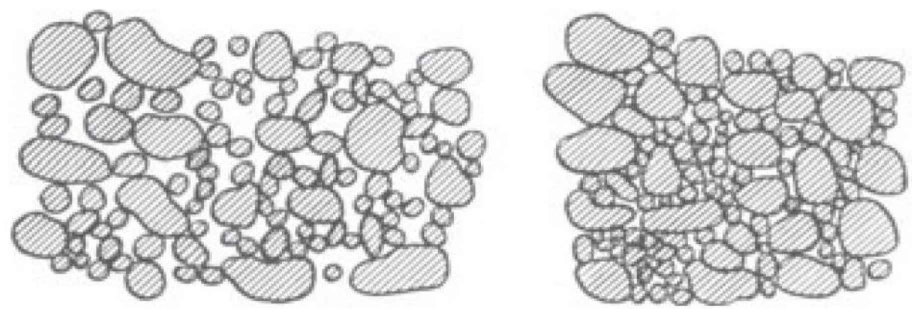
Background

Compaction in earthworks – purpose

compaction leads to increase of number of grain-to-grain-contacts and reduction of pore space

→ increase in shear strength, load-bearing capacity and stiffness

→reduced setting potential



[Keil, 1954]

to ensure stability and long-term serviceability application-related requirements for the minimum degree of compaction to be achieved in the field

if required degree of compaction is achieved, sufficient compaction can be assumed

Background

Compaction in earthworks – requirements

test criterion: **degree of compaction $D_{Pr} = \rho_{d,field}/\rho_{Pr}$**

e.g. planum:

	Bereich	Bodengruppen	D_{Pr} in %
1	Planum bis 1,0 m Tiefe bei Dämmen und 0,5 m Tiefe bei Einschnitten	GW, GI, GE SW, SI, SE GU, GT, SU, ST	100

[ZTV E-StB 17, Table 4]

e.g. protecive walls: $D_{Pr} \geq 97$ %

possible test criteria: **D_{Pr}, E_{vd}, E_{v1},…**

Tiefenbereich	E_{vd} [MN/m²]	E_{v1} [MN/m²]	D_{Pr} [%]
Unterbauplanum	38	35	100
ab 1 m unter Unterbauplanum	24 (26)	20	99
ab Dammaufstandfläche (einschl. Bodenauswechslung)	18 (16)	15 (7,5)	97 (95)
Hinterfüllung	38	35	100

[RVS 08.03.01, Table 1]

→if requirements have been achieved has to be checked by compaction control

Background

Compaction in earthworks – compaction control

basic distinction

direct testing → direct determination of the respective requirement value

<u>examples</u>

- determinaion of dry density with volume replacement methods to prove degree of compaction
- determination of subgrade modulus E_V with static or dynamic plate load test to prove required subgrade modulus

relationship testing

use of relation between stiffness and dry density of the subsoil

→determination of subgrade modulus to prove degree of compaction

Background

Compaction in earthworks – relationship testing in Germany

use of the relationship between the stiffness of the subgrade and dry density

for coarse and mixed grained soils

→ relationship has to be determined within the scope of test fields

for coarse grained soils with fines content ($d < 0{,}063$ mm) < 5 % by mass

→ use of table values possible (based on natural materials, used for decades in practice)

static plate load test

Bodengruppe	*statischer Verformungsmodul E_{v2} in MPa*	*Verdichtungsgrad D_{Pr} in %*
GW, GI	≥ 100 ≥ 80	≥ 100 ≥ 98
GE, SE, SW, SI	≥ 80 ≥ 70	≥ 100 ≥ 98

$E_{v2}/E_{v1} \leq 2{,}3$ für $D_{Pr} \geq 100$ %

$E_{v2}/E_{v1} \leq 2{,}5$ für $D_{Pr} \geq 98$ %

dynamic plate load test

Bodengruppe	*dynamischer Verformungsmodul E_{vd} in MPa*	*Verdichtungsgrad D_{Pr} in %*
GW, GI, GE, SW, SI, SE	≥ 50 ≥ 40	≥ 100 ≥ 98

Compaction control of secondary materials

Compaction control of secondary materials

field tests conducted

July 2017

June 2018

Compaction control of secondary materials

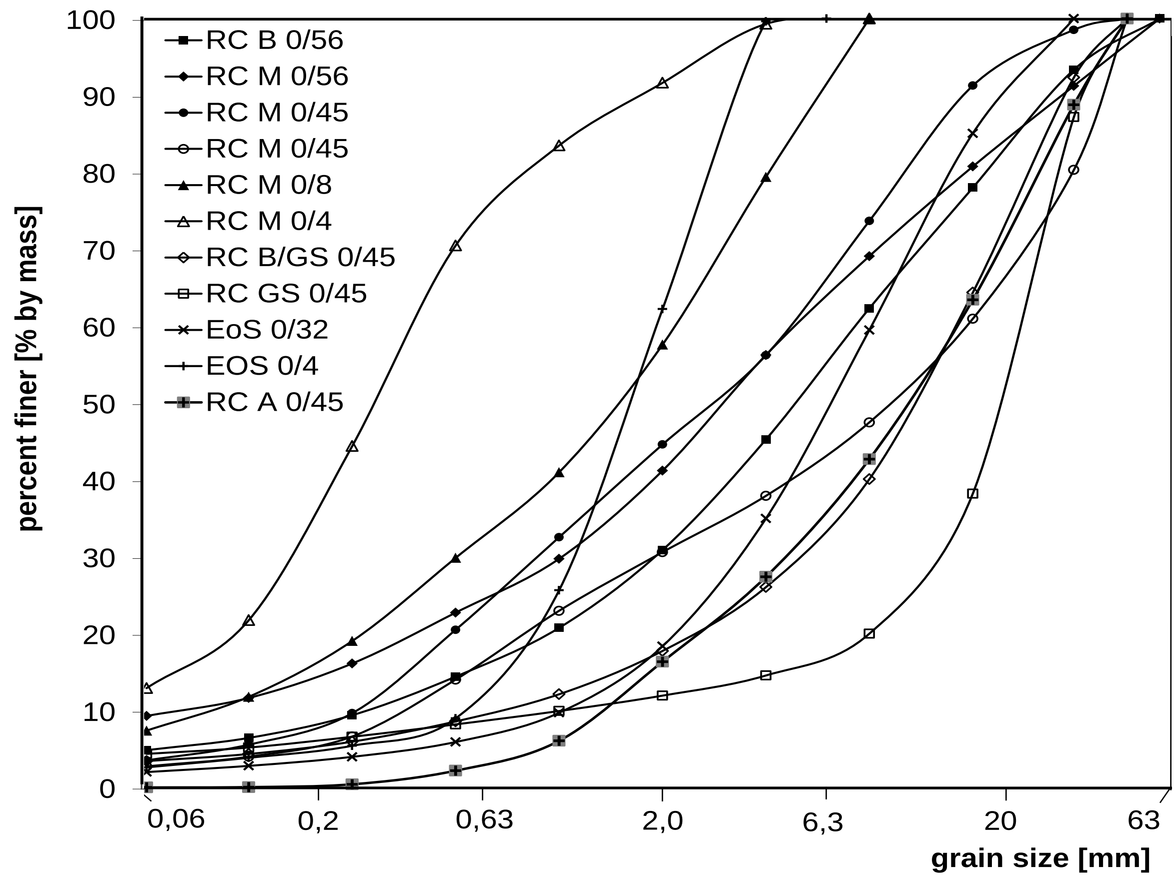
materials tested

July 2017

recycled concrete (RC B 0/56)
recycled construction waste mix (RC M 0/56)
recycled construction waste mix (RC M 0/45)
recycled construction waste mix (RC M 0/8)
electric furnace slag (EOS 0/32)
electric furnace slag (EOS 0/4)

June 2018

recycled construction waste mix (RC M 0/45)
recycled construction waste mix (RC M 0/4)
recycled concrete/railway ballast (RC B/GS 0/45)
recycled railway ballast (RC GS 0/45)
recycled asphalt (RC A 0/45)



Compaction control of secondary materials

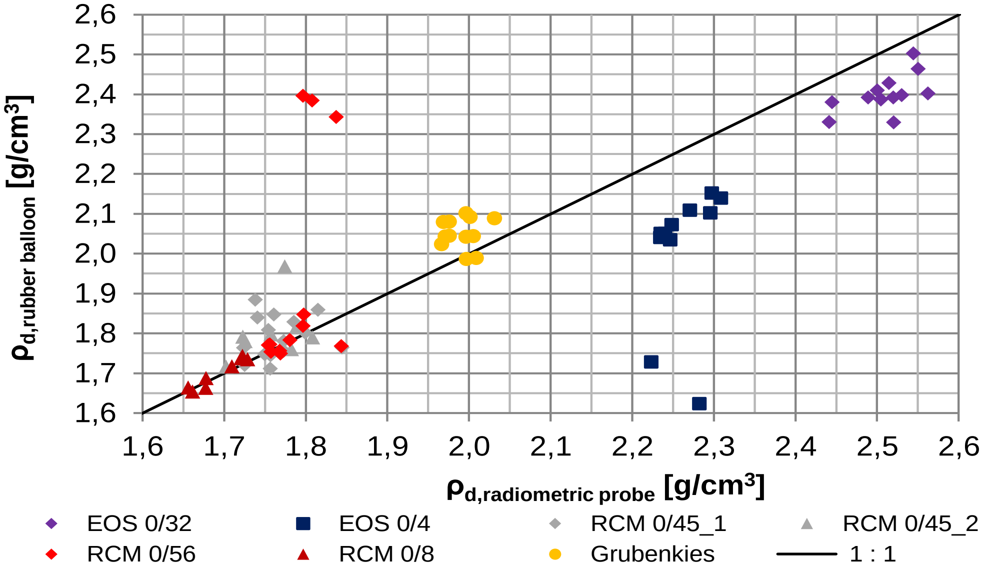
direct testing methods

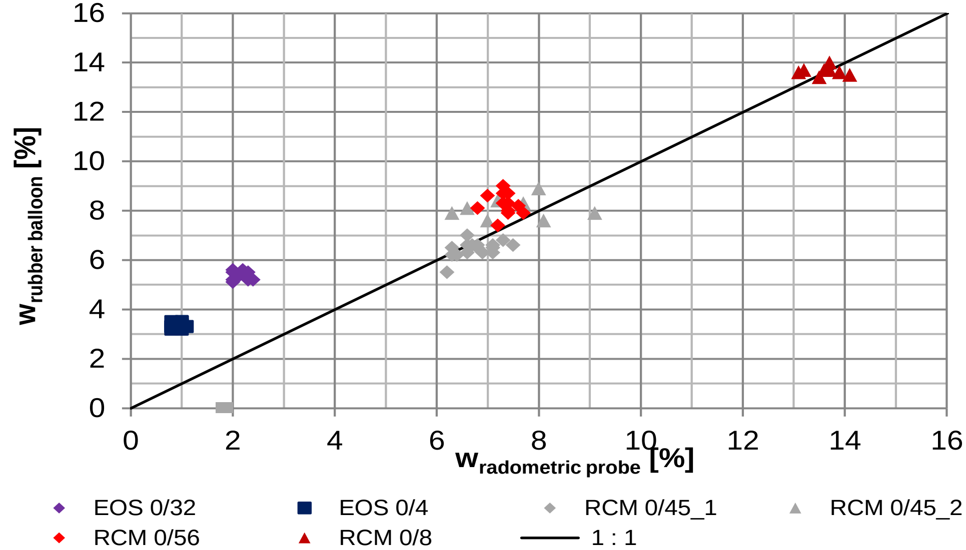
rubber balloon method

radiometric probe

Compaction control of secondary materials

direct testing methods – comparison *rubber balloon method* and *radiometric probe*





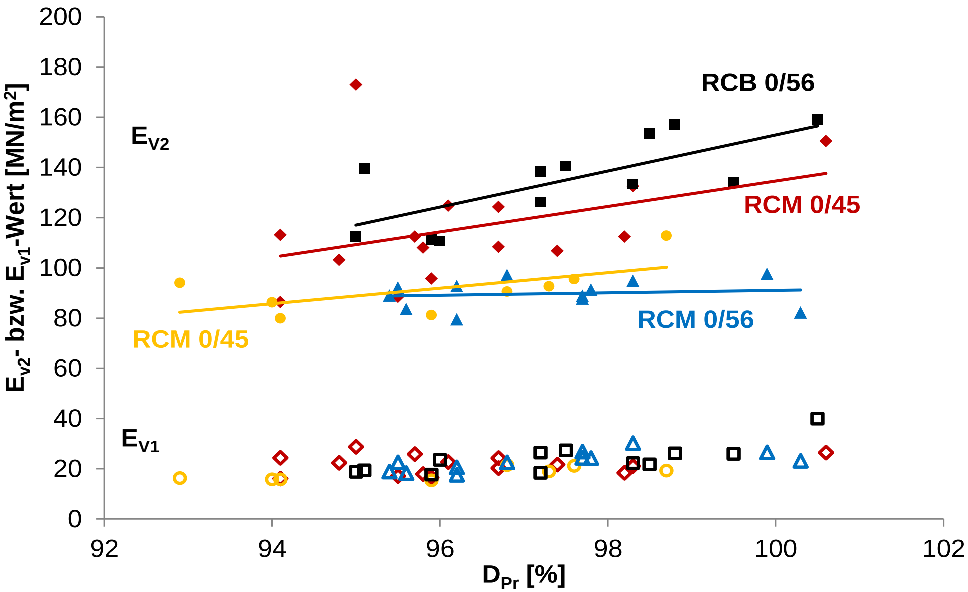
- volume replacement methods (like rubber balloon method) applicable, but difficulties in determination of the correct test volume (e.g. due to elasticity of the rubber balloon)

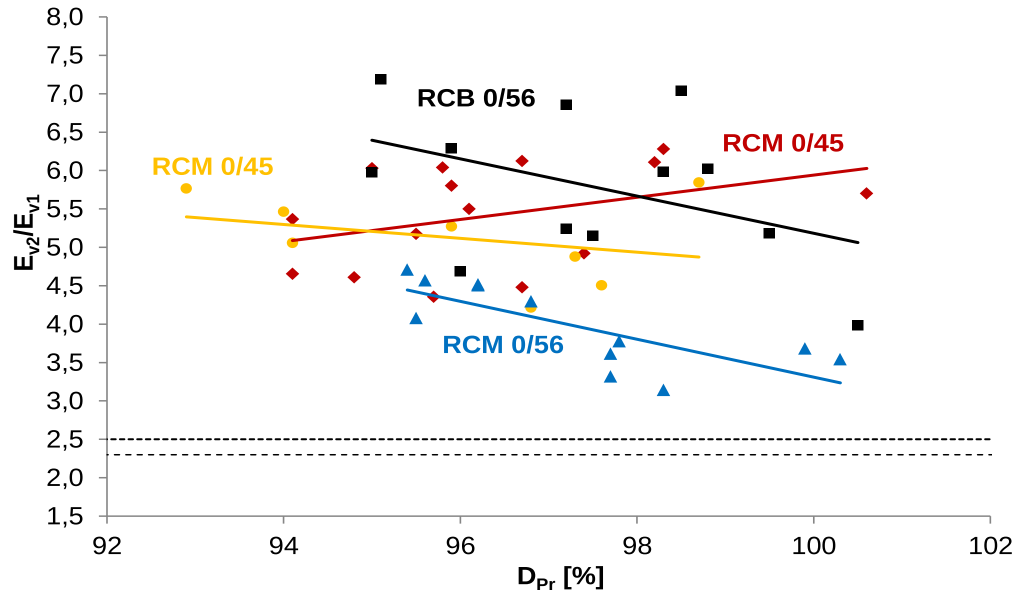
- accuracy of the radiometric probe depends on correct calibration of the probe → differences in the mineralogical composition of secondary materials can lead to errors in measurement

  → e.g. ion contents can lead to too high densities and too low water contents

Compaction control of secondary materials

relationship testing – static plate load test





→ static plate load test applicable for relationship testing

→ high subgrade moduli E_{V2} with sufficient degree of compaction

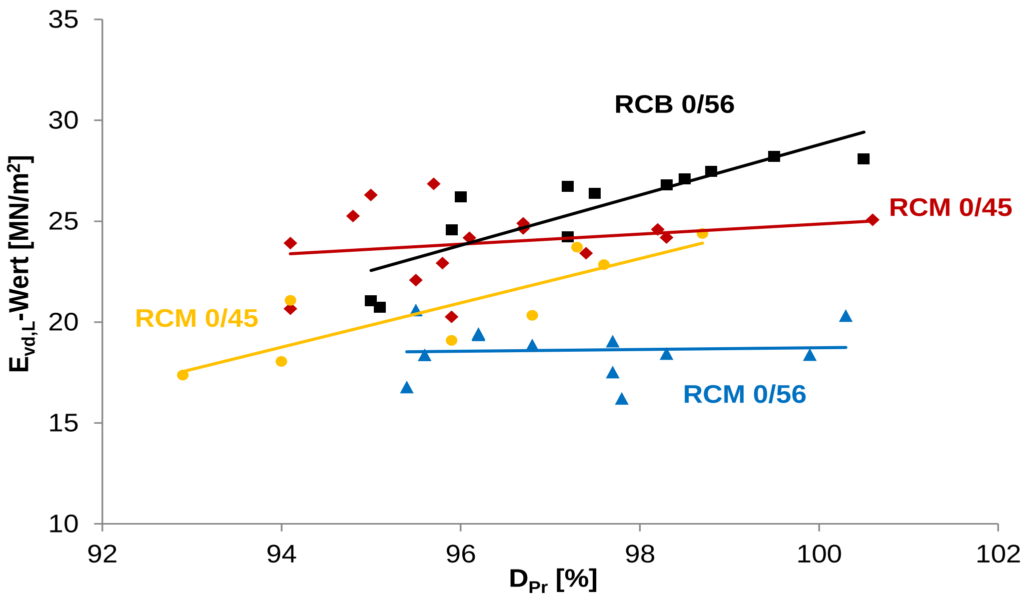
→ low subgrade moduli E_{V1}

→ high ratio E_{V2}/E_{V1} due to high subgrade moduli E_{V2} and low subgrade moduli E_{V1}

high ratio E_{V2}/E_{V1} and low subgrade moduli E_{V1} can lead to difficulties in connection with German and Austrian guideline values

Compaction control of secondary materials

relationship testing – dynamic plate load test



→dynamic plate load test applicable for relationship testing

→low subgrade moduli E_{Vd} despite sufficient degree of compaction

low subgrade moduli E_{Vd} can lead to difficulties in connection with German and Austrian guideline values

Conclusion

recylced materials and industrial by-products are basically suitible as construction materials in earthworks and a suitible alternative to primary building materials

in addition to structural suitability, environmental suitability must also be considered

meaningful application requires consideration of material characteristic properties of recycled materials and industrial by products

→ compaction control with direct testing methods and by relationship testing
→ compactability

Thank you for your attention!

Questions?

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