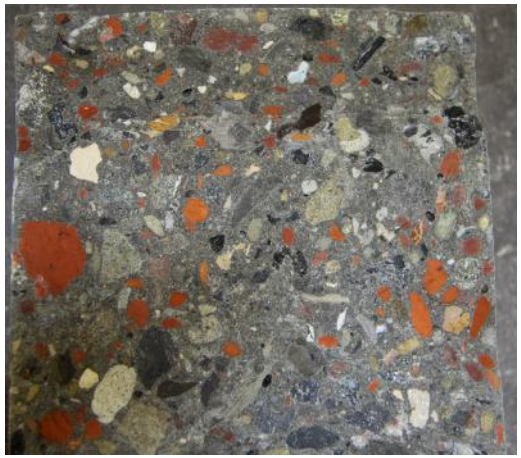
Interreg North-West Europe SeRaMCo
European Regional Development Fund

TECHNISCHE UNIVERSITÄT KAISERSLAUTERN

Special challenges for concrete containing recycled aggregates from unknown origin



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Recycled aggregates from unknown origin

Crushed concrete

Mixed aggregates

Preparation of the aggregates by the recycler:

- Sorting and elimination of metals, wood, etc.
- Washing to remove fines
- Remove sand (fraction 0/2 mm)
- Sieving into three fractions:
  - 2/6 mm
  - 6/14 mm
  - 14/22 mm

Recycled aggregates consisting of **different materials**, such as crushed concrete, bricks, ceramics, asphalt and others, with **different mechanical and physical/chemical properties and great variations concerning the composition**

Challenges

Differences in composition and raw material properties influence the resulting properties of concrete

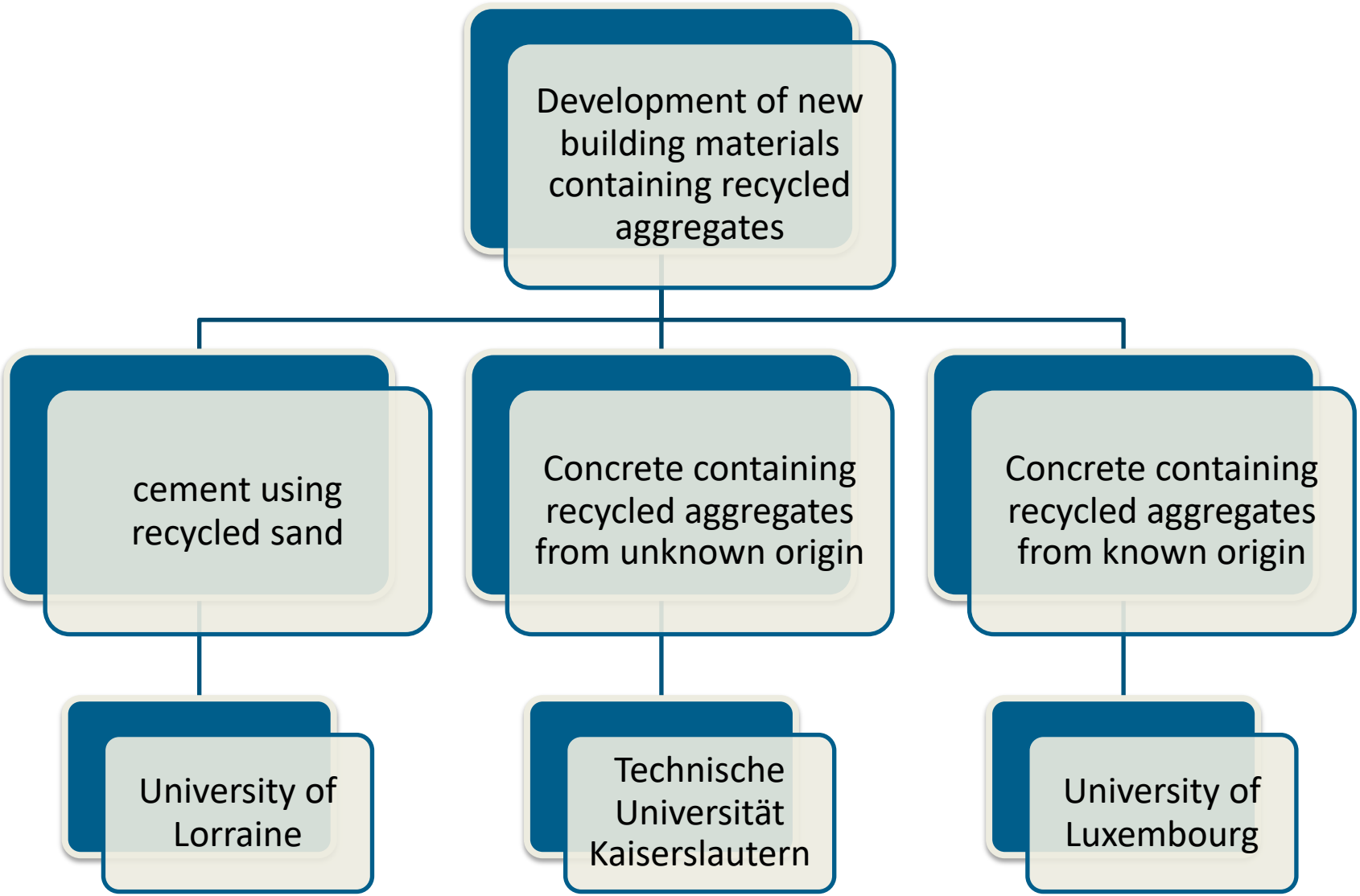
Fresh concrete:

- Workability
  (Higher water absorption of aggregates)

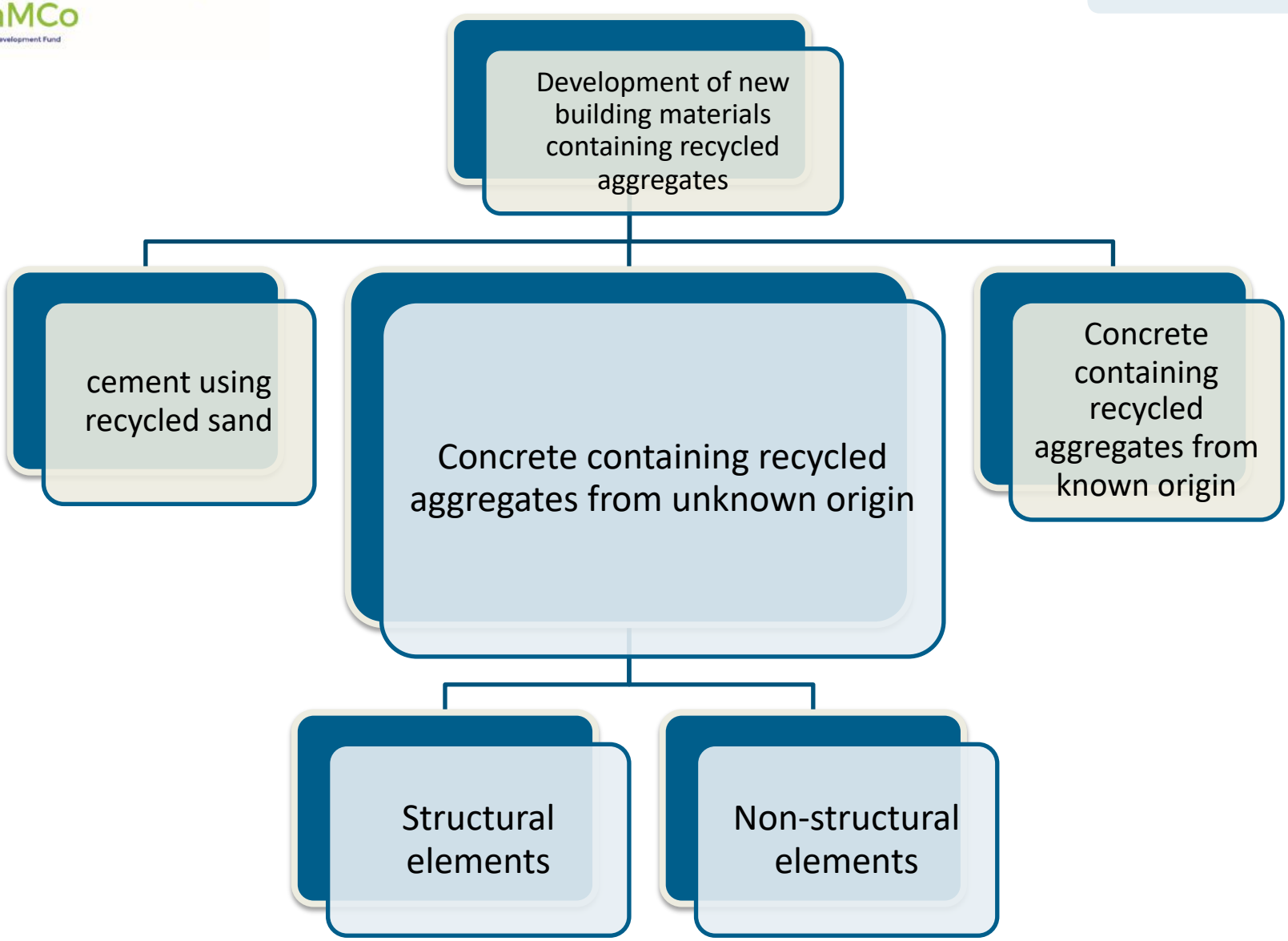
Hardened concrete:

- Strength
  (compressive strength and tensile splitting strength)
- Deformation behavior
  (modulus of elasticity, shrinkage, creep)
- Durability
  (alcali silica reaction (ASR), chloride-migration, carbonation, freeze-thaw-resistance, abrasion resistance)

Aims


Development of new building materials containing recycled aggregates
cement using recycled sand
Concrete containing recycled aggregates from unknown origin
Concrete containing recycled aggregates from known origin
University of Lorraine
Technische Universität Kaiserslautern
University of Luxembourg

Aims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Structural elements
Non-structural elements

Research Plan

Characterization of aggregates

- composition
- gross density
- water absorption
- grading

Development of a concrete mixture for structural elements

- Development of a concrete mix containing recycled aggregates which is able to fulfill the requirements

Development of a concrete mixture for non-structural elements

- Development of a concrete mix containing recycled aggregates which is able to fulfill the requirements

Aim: ideally replacing rate of 100 %

concrete properties should match requirements of EN 206 and EN 1992-1-1 (EC 2)

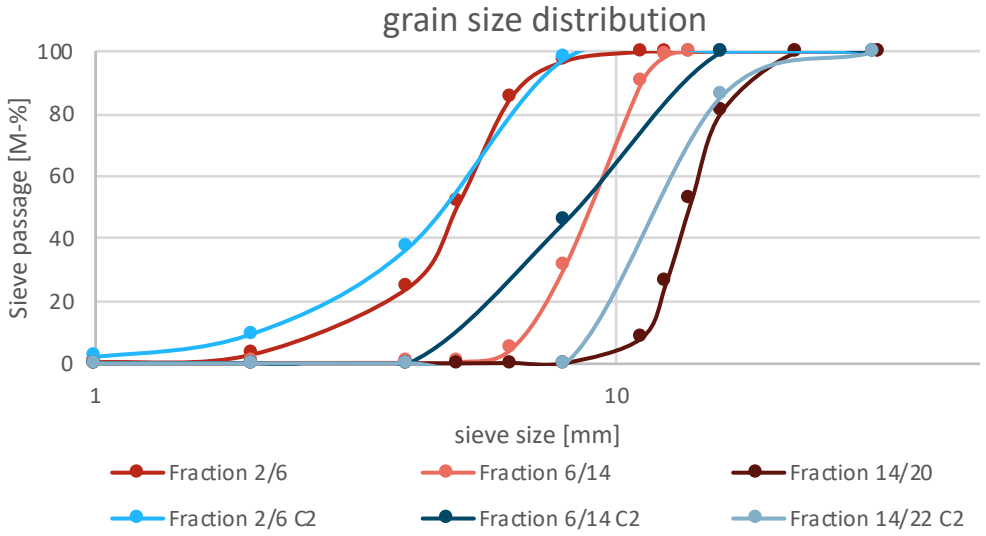
modifications of replacing rate and/or design values if necessary

Characterization of crushed concrete aggregates

Type A	Ammount [wt.-%]
$R_c + R_u$	≥ 95
R_c	≥ 90
R_b	< 10
R_a	< 1
$X + R_g$	≤ 1
Fl	≤ 2

Category according to EN 206:

→ Type A
Except $R_a > 1$



$W_{24} \approx 4$ to 5 %

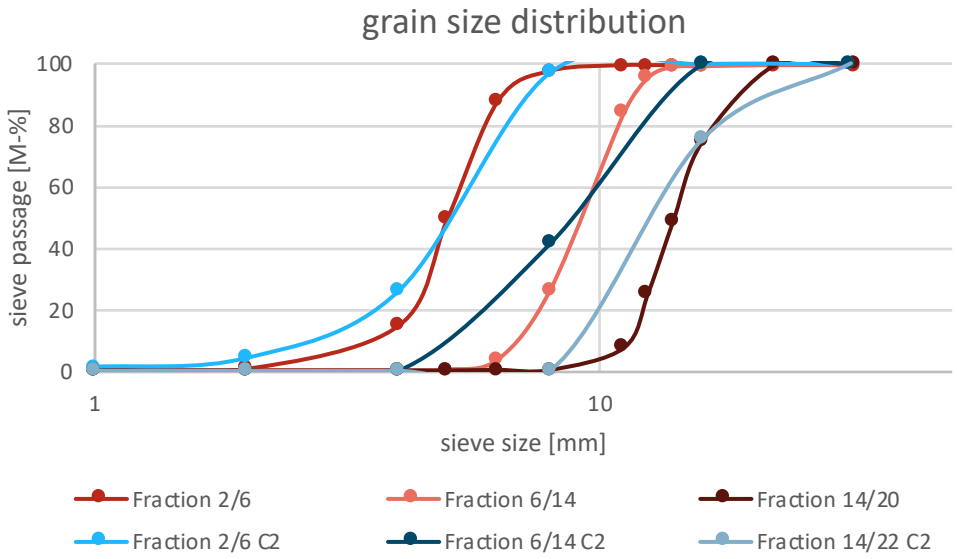
$\rho_a = 2.7$ Mg/m³
$\rho_{rd} = 2.3$ Mg/m³
$\rho_{ssd} = 2.5$ Mg/m³

Characterization of mixed recycled aggregates

Type B	Ammount [wt.-%]
$R_c + R_u$	≥ 70
R_c	≥ 50
R_b	≤ 30
R_a	< 5
$X + R_g$	≤ 2
Fl	≤ 2

Category according to EN 206:

→ Type B



$W_{24} \approx 6$ to 9 %

$\rho_a = 2.5$ Mg/m³
$\rho_{rd} = 2.2$ Mg/m³
$\rho_{ssd} = 2.3$ Mg/m³

Development of the concrete mix for structural elements

Materials:

- CEM I 42,5
- Natural sand 0/2 mm
- Aggregates: crushed concrete and mixed aggregates

Requirements: (in relation to the planned elements)

- C30/37; C35/45
- Cement + k x addition > 385 kg/m³
- w/b ≤ 0.45; w/b ≤ 0.5
- Consistency F3

Test matrix:

Changing of properties depending on the w/b ratio

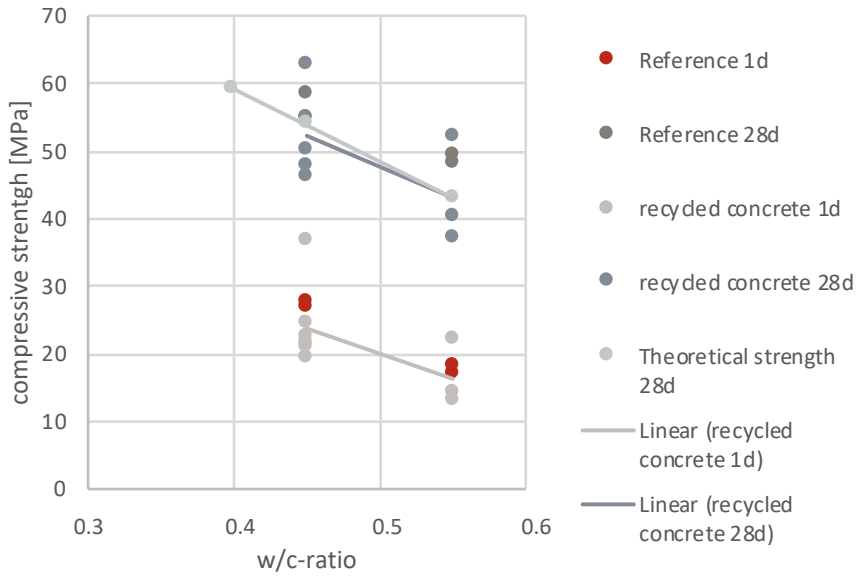
Parameter	Variation levels	
w/b ratio	2	0.45; 0.50
aggregates	3	Natural aggregates; Crushed concrete; mixed aggregates
Ratio of recycled aggregates	4	100%, 75%, (50%, 25%)

All tests have to be retried with further charges of recycled aggregates

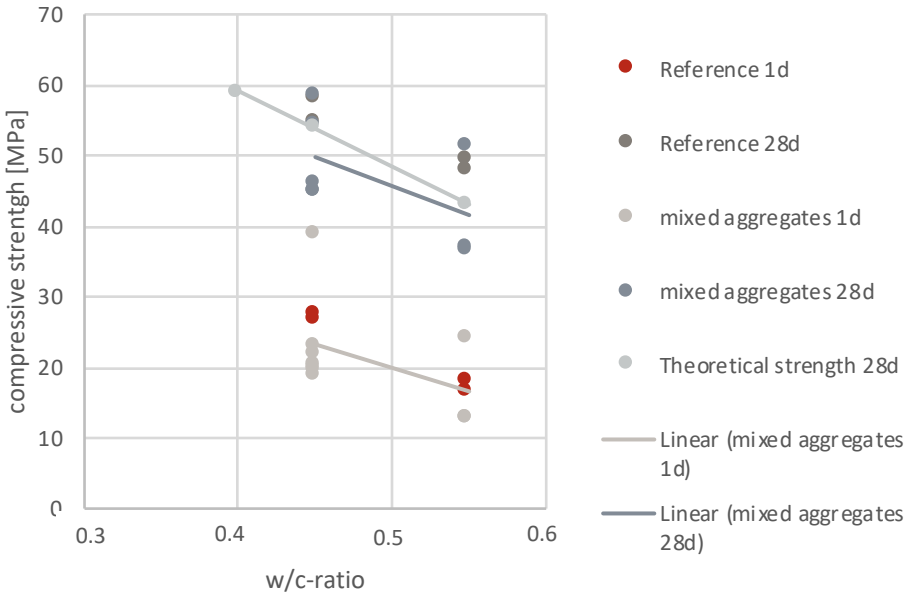
Development of the concrete mix for structural elements

Results:

Compressive strength crushed concrete samples

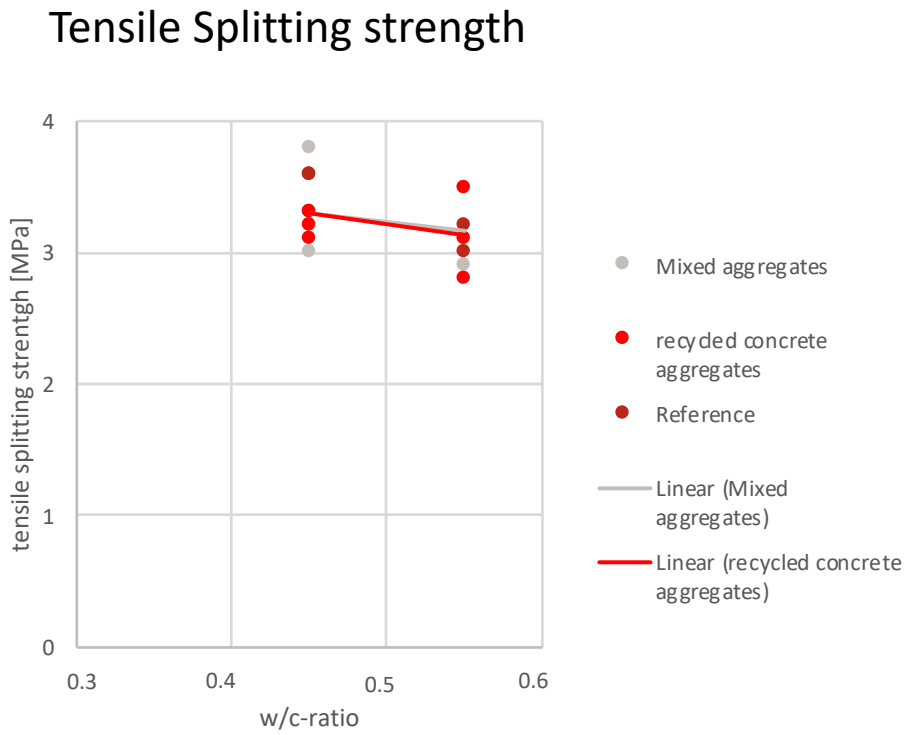


Compressive strength mixed aggregates samples



Development of the concrete mix for structural elements

Results:



specimen:
cube 150 mm x 150 mm + 150 mm
28 d, storage under water

Development of the concrete mix for non-structural elements/ paving blocks

Requirements: EN 1338

physical and mechanical properties

- **resistance against athmospheric conditions** (freeze-thaw-resistance or water absorption)
- **splitting tensile strength**
- durability and strength
- **abrasive resistance**
- slip resistance
- thermal conductivity

additional requirements concerning form and dimension of products

Development of the concrete mix for non-structural elements/ paving blocks

production process

batching and mixing

- most important factor = moisture content of aggregates!
- differences in water content lead to differences in quality

moulding and compacting

- compacting by vibration and an additional compressive force
- amount of mixture compacted up to predetermined height or compacting a gauched quantity for a set period
- multilayer machines or single layer machines

curing

- in curing chambers by moisture retention (most spread)
- steam curing or thermal curing (less important)

Development of the concrete mix for non-structural elements/ paving blocks

production process

types of products:

concrete pavers with or without topping layer

concretes:
no-slump concretes with low water/cement ratios (< 0.40) optimum content of cement and water, well graded aggregates, if necessary admixtures and colour pigments

mixing proportions depend on

- materials (cement, aggregates, admixtures …)
- manufacturing equipment and production process
- required quality (strength, durability, texture, form …)

not practicable to look for optimum in proportioning under laboratory conditions!

Development of the concrete mix for non-structural elements/ paving blocks

Requirements:

- Slump 0
- Minimum content of cement
- Splitting tensile strength ≥ 3.6 MPa
- High abrasion resistance and high freeze-thaw resistance
  → likely it will be needed to develop a two-layered paving block (core concrete containing recycled aggregates and facing concrete containing natural aggregates)

Test flow:

Influence of the test setup

- Influence of compaction by the test setup has to be tested
- 3 variations
  > only vibration
  > vibration + 100 bar Pressure
  > vibration + 200 bar pressure

→

Reference

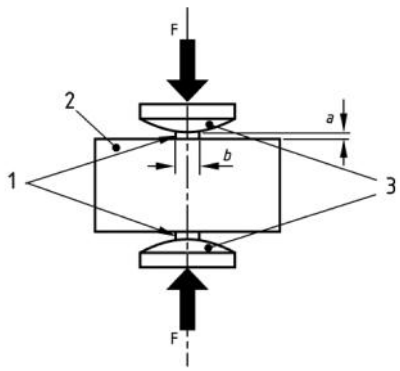
- Development of a concrete mix containing natural aggregates which is able to fulfill the requirements

→

Paving blocks made of recycled aggregates

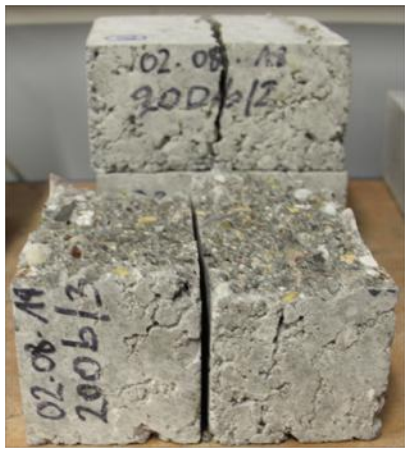
- Transfer the reference mix to the mix containing recycled aggregates
- Used aggregates: crushed concrete, mixed aggregates
- Variing the ratio of recycled aggregates starting with 100%

Development of the concrete mix for non-structural elements/ paving blocks



Test setup according to EN 1338:

1. Load spreading strips
2. Paving stone
3. Stiff load application



Content of cement	250 kg/m³			275 kg/m³		
	P/l	T	s	P/l	T	s
	[N/mm]	[MPa]	[MPa]	[N/mm]	[MPa]	[MPa]
natural gravel	484.9	3.9	0.82	389.9	4.7	1.31
crushed material	405.9	3.3	0.77	589.6	4.8	0.57
recycled aggregates (crushed concrete)	369.4	3.0	0.37	471.9	3.9	0.23
mixed aggregates	241.2	2.0	0.20	373.6	3.0	0.42

requirements	
T_m	≥ 3.6 MPa
T_i	≥ 2.9 MPa
P/l	≥ 250 N/mm

P/l = ultimate load/break line – ratio [N/mm]
T = tensile splitting strength [MPa]
s = standard deviation [MPa]

specimen l/b/h = 150 mm/150 mm/75 mm
compaction by vibration on vibro-table under additional load (steel-plate)
storage: 1 d in mould, 27 d exposure to air

Outlook

Next steps:

- Testing the durability of the developed mixtures
- Testing the performance of the new concrete mixes, when the ordinary cement (OPC) is exchanged by the new cements developed in the other part of the project

Thank you for your attention!