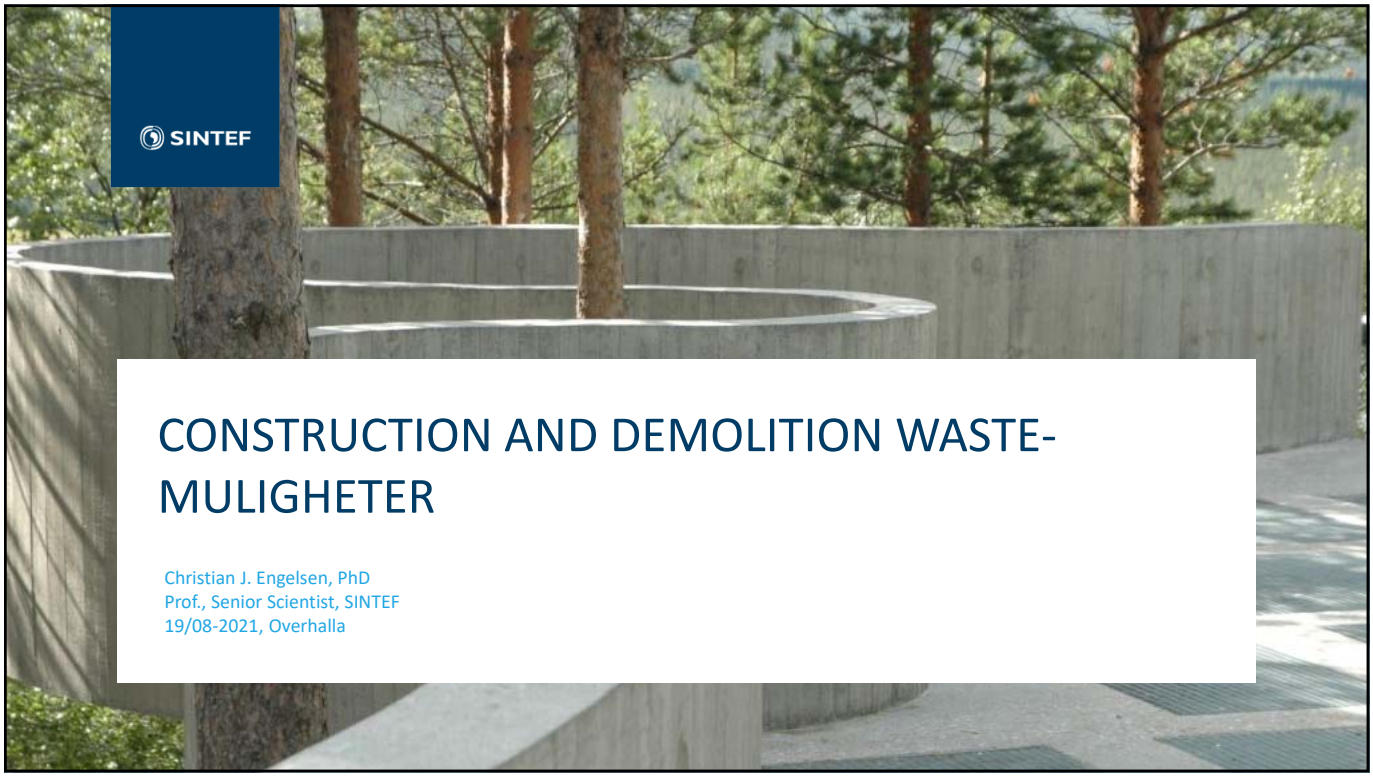


CONSTRUCTION AND DEMOLITION WASTE-MULIGHETER

Christian J. Engelsen, PhD
Prof., Senior Scientist, SINTEF
19/08-2021, Overhalla

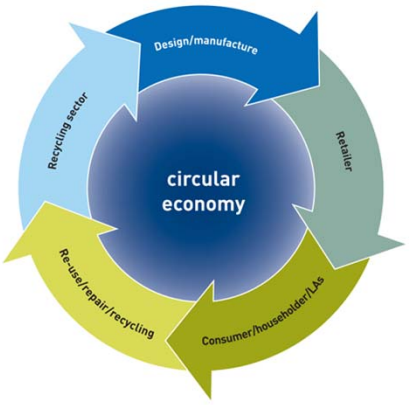
1

Reuse and recycling

Why is it important and what is the potential?

2

Circular Economy approach



> "The whole idea of a circular economy is to keep materials and energy in a never ending cycle."

- SINTEF has strong focus on R&D projects that contribute to Circular Economy.

The concepts needs to be economic and ecologic sustainable

SINTEF

What is C&D waste?

~50% by weight is concrete and masonry

SINTEF

5

6

7

8

9

10

11

Generation of C&D waste

Volume (mill. tons)	Europa[a]	USA[a]	India[b]	Japan[a]	Norge
C&D waste	510	317	60-530	77	1.9[c]
Municipal waste	241	228	62	53	2.4[d]

[a] The Cement Sustainability initiative - Recycling Concrete; World Business Council for Sustainable Development
[b] Planning Commission 2014; Sekhar et al. 2016, Resource efficiency in the construction sector, GIZ report.
[c] Statistics Norway 2014 – waste from civil engineering sector is not included
[d] Statistics Norway 2014 – from private households

12

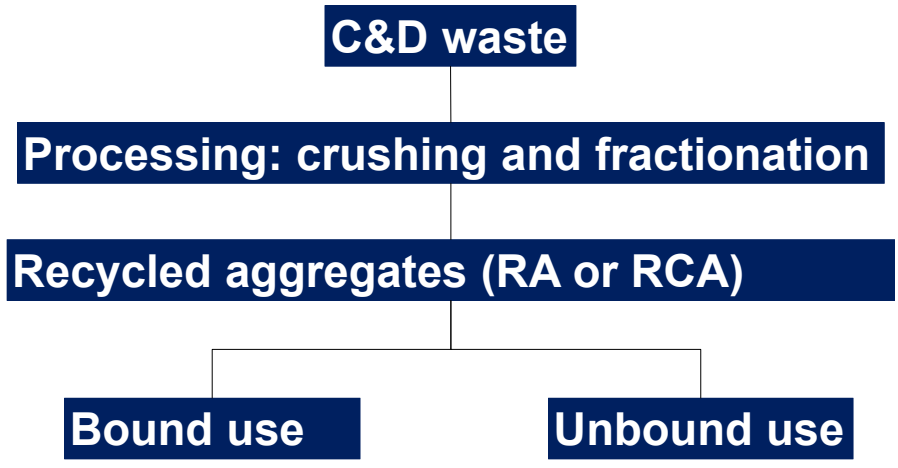
SINTEF

12

Why is recycling of C&D waste important?

SINTEF

13



14

SINTEF

14

Potential use for recyceled C&D waste

- Ready-mix concrete
- Concrete products
- Road construction
- Landscaping and covering masses
- Cement production
- Other mineral building products

SINTEF

15

16

Important prerequisites

1. Quality of of the recycled products
2. Avilability of the recycled products
3. Cost efficiency that make the products competitive
4. Flexible and dynamic regulatory system
   - ✓ Technical standards and environmental standards
   - ✓ Criteria for segregation and recycling
   - ✓ Incentives for segregation and recycling

SINTEF

17

Implementation in European standards

Table 1 EN standards which include the use of recycled aggregates

User application	EN standard
Concrete production	EN 12620
Lightweight aggregates for concrete, mortar and grout	EN 13055-1
Lightweight aggregates for bituminous mixtures and surface treatments	EN 13055-2
Mortar	EN 13139
Track ballast	EN 13450
Road construction and civil engineering	EN 13242

Ng, S. and Engelsen, C.J., 2018. *Construction and Demolition wastes*, In: Waste and Supplementary Cementitious Materials in Concrete: Characterisation, Properties and Applications. Editors: Rafat Siddique and Paulo Cachim, Elsevier publication, in print.

SINTEF

18

Replacement levels in concrete according to NS-EN 206 NA

Tabell NA.6 – Største andel av tilslag i fraksjon 0/4 mm som kan erstattes med resirkulert tilslag

Trykkfasthetsklasse og bestandighetsklasse	Andel resirkulert tilslag		
	Type AN	Type BN	Sum Type AN + BN
Trykkfasthetsklasse ≤ B25 og bestandighetsklasse M90	10 %	5 %	10 % [a]

[a] Dersom begge typer benyttes, gjelder også begrensningen på 5 % av Type BN.

Tabell NA.7 – Største andel av tilslag i fraksjon 4/32 mm som kan erstattes med resirkulert tilslag

Trykkfasthetsklasse og bestandighetsklasse	Andel resirkulert tilslag		
	Type AN	Type BN	Sum Type AN + BN
Trykkfasthetsklasse ≤ B25 og bestandighetsklasse M90	30 %	10 %	30 % [a]
Trykkfasthetsklasse ≤ B45 og bestandighetsklassene M90 og M60	20 %	0 %	-

[a] Dersom begge typer benyttes, gjelder også begrensningen på 10 % av Type BN.

SINTEF

19

20

21

22

23

24

Filter press fraction demonstrated in full scale in concrete pavament blocks

Up to 14 % reduced cement content

SINTEF

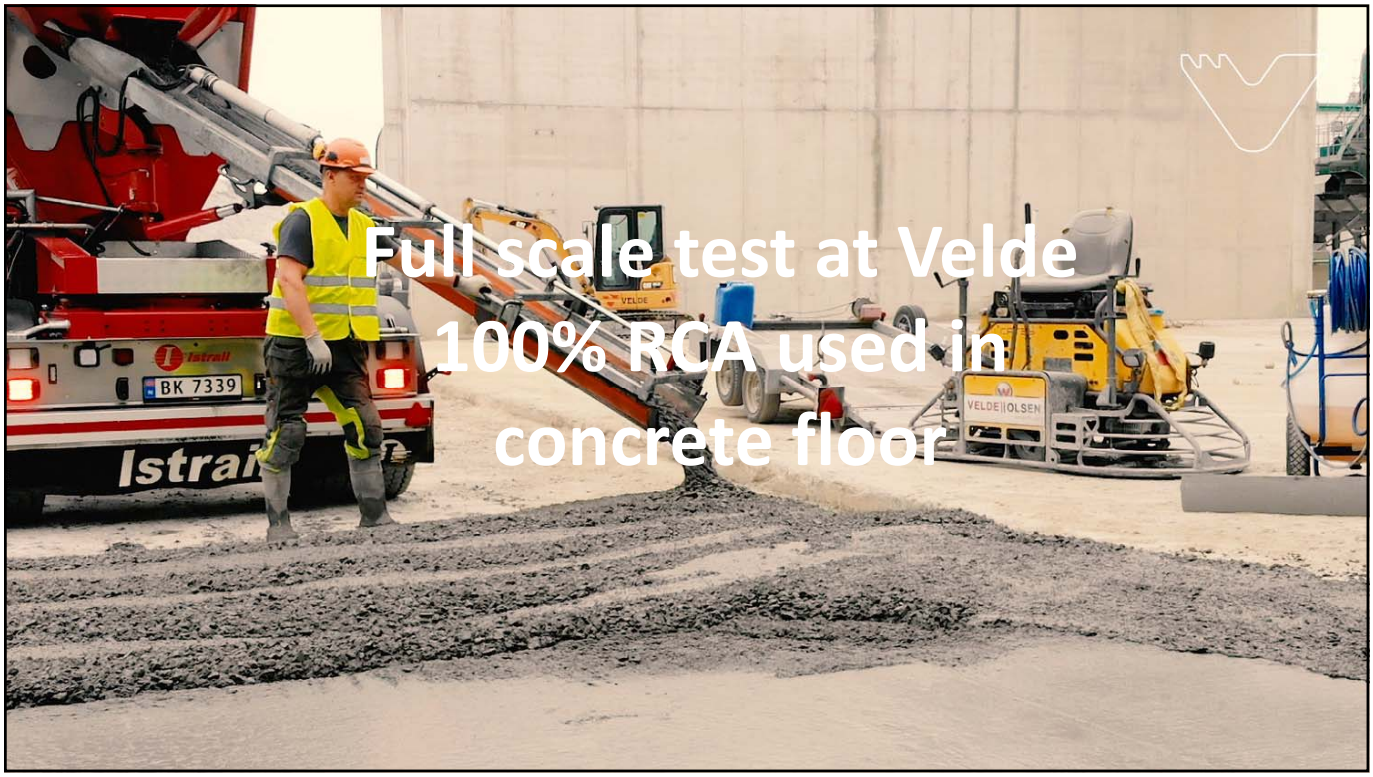
25

Concrete pavement blocks – recipe

Material	Unit	Amount
Cement	kg/m^3	354
Coarse aggregate (4/8 mm)	kg	261
Fine Aggregate (0/4 mm)	kg	1565
Filterpress (< 63 µm)	kg	17.4
Admixture (P)	kg	0.042
Water cement ratio	-	102

SINTEF

26



27

Concrete mix design

Material	Unit	Amount
Cement content (CEM II/A-V) in concrete	kg/m^3	365
Water to cement ratio (w/c)	-	0.45
Admixture (Dynamon SX-N) content of cement weight	%	0.9
Steel fibre in concrete	kg/m^3	25
RCA 0/2 mm	kg/m^3	750
RCA 4/16 mm	kg/m^3	747
RCA 16/32 mm	kg/m^3	374

SINTEF

28

Results obtained in fresh and harden state[a]

Material properties	Sample 1	Sample 2	Sample 3
Density (g/dm^3)	2388	2380	2367
Slump (mm)	180	200	190
Fresh concrete temperature (°C)	21.2	22.0	21.0
Compressive strength after 2 days (MPa)	22.1	26.1	25.6
Compressive strength after 28 days (MPa)[b]	56.9	60.4	64.9
Density after 28 days (g/dm^3)	2438	2383	2403

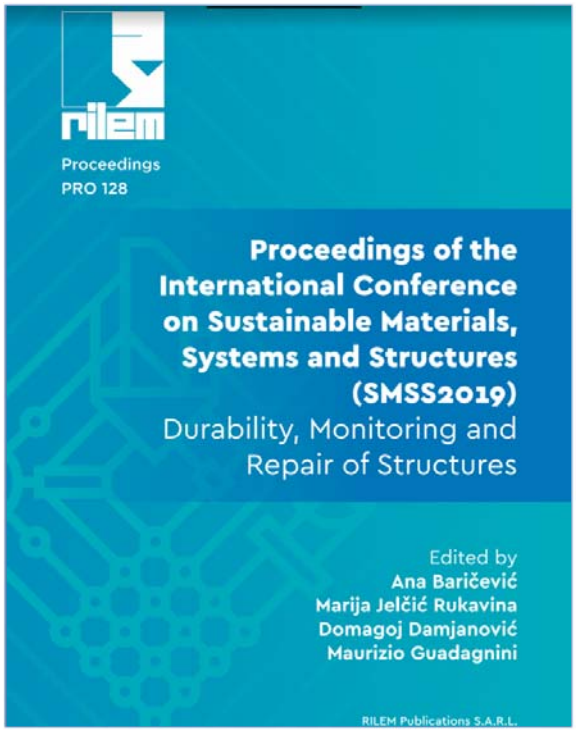
[a] Mujica, H., Velde E., Engelsen, C.J., Nodland, M.S., Recycled aggregates produced from two different feedstock materials – Applied in ready-mixed concrete, RILEM Spring Convention 2019, Croatia.

[b] Typical reference strength of concrete produced with crushed natural aggregates is 58 MPa

SINTEF

29

30



International Conference on Sustainable Materials, Systems and Structures (SMSS 2019)
New Generation of Construction Materials
20-22 March 2019 – Rovinj, Croatia

RECYCLED AGGREGATES PRODUCED FROM TWO DIFFERENT FEEDSTOCK MATERIALS – APPLIED IN READY-MIXED CONCRETE

Hernan Mujica (1), Egil Velde (1), Christian J. Engelsen (2), Monica S. Nodland (2)

(1) Velde Industri AS, Norway

(2) SINTEF Building and Infrastructure, Norway

Abstract

Construction and demolition waste (CDW) and waste excavation materials (WEM) from construction activities are important raw materials for new construction materials and products. Recycled concrete aggregates (RCA) from both waste streams are today not used in bound applications (e.g. ready-mixed concrete).

In this study, RCA was produced from a feedstock with 50% of each waste stream (WEM and CDW) and used in concrete pilot. The RCA replaced fully the natural aggregates in the concrete mix. It was found that the compressive strength complied to the requirements for C35/45 in NS-EN 206. Furthermore, the use of this type of RCA had no negative impact on the physical characteristics of the RCA and the concrete. Low content of cement paste was found in the RCA and resulted in low water absorption. This demonstrated the ability of the wet recycling process to remove significant quantities of the mortar in the CDW.

The total concentrations of inorganic and organic substances were found to be low and complied to the strict Norwegian soil quality criteria. Cr(total) exceeded the criteria. However, most of the chromium was present on the trivalent form, Cr(III), which has low solubility in the neutral to mildly basic pH region.

Keywords: Recycled aggregates, concrete, pilot demonstration

1. INTRODUCTION

The revised framework for waste management in the EU [1] which was adopted in 2008 includes a target for recovery of construction and demolition waste (CDW). Within 2020, the preparing for re-use, recycling and other material recovery of non-hazardous construction and demolition waste (excluding naturally occurring material) shall be increased to a minimum of 70 % by weight. The target was added during the final negotiations of the Directive text and instructions for verifying compliance was established in 2011 [2]. Norway has implemented the

272

SINTEF

31

Added value property – CO2 binding capacity

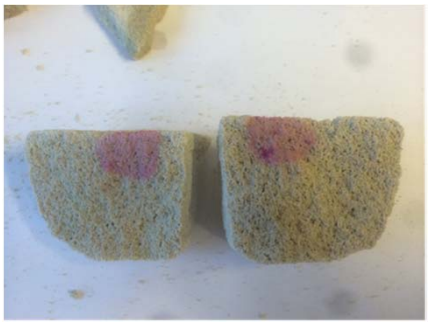
SINTEF

32

Natural CO_2-binding by carbonation

$CaCO_3$ + heat = $CaO + CO_2$ **Cement prodcution**

$CaO + CO_2 = CaCO_3$ **Carbonation when exposed to air**



SINTEF

Carbonation of main hydrate phases

$CO_2 + H_2O \Rightarrow H_2CO_3$

$Ca(OH)_2 + CO_2 \Rightarrow CaCO_3 + H_2O$

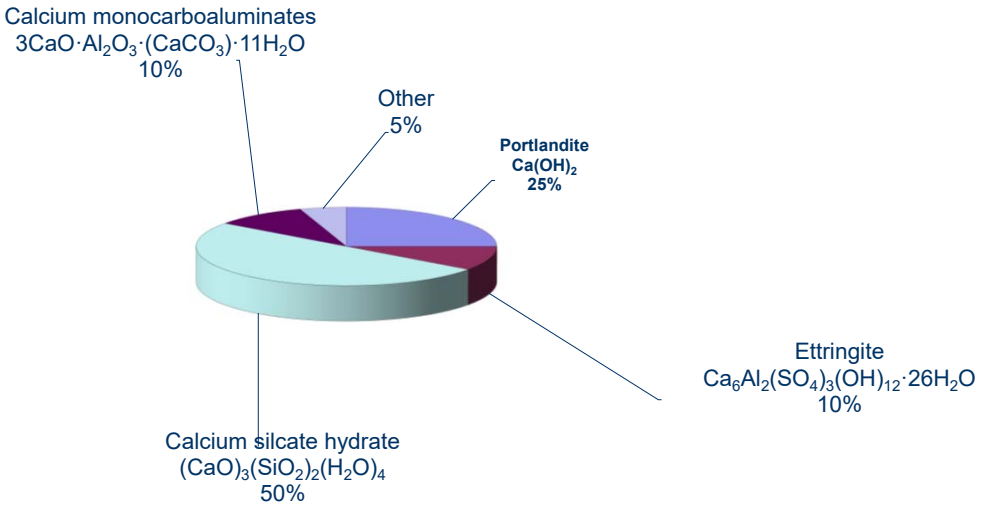
$(CaO)_3(SiO_2)_2(H_2O)_4 + 3CO_2 \Rightarrow 3CaCO_3 + (SiO_2)_2(H_2O)_{4-w} + wH_2O$

$Ca_6Al_2(SO_4)_3(OH)_{12}\cdot 26H_2O + 3H_2CO_3 \Rightarrow 3CaCO_3 + 3CaSO_4\cdot 2H_2O + 2Al(OH)_3 + 26H_2O$

$(CaO)_3Al_2O_3(CaCO_3)\cdot 11H_2O + 3CO_2 + 3H_2O \Rightarrow 4CaCO_3 + 2Al(OH)_3 + 11H_2O$

SINTEF

Portland cement paste – phase assembly



SINTEF

What is the binding capacity of cements?

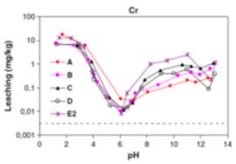
Cement type	Fly ash (%)	Slag (%)	CO_2-binding capacity (kg/t)
CEM I	Not applicable	Not applicable	330
CEM II/A-V[1]	20	Not applicable	255
CEM II/B-S[2]	-	33	294

SINTEF

RECONC - Recycled aggregates from concrete sludge (RACS) with CO_2-binding properties and reduced leaching 2020-2024

37

RECONC project details



Objective

To develop recycled aggregates from concrete sludge (RACS) that comply to the same criteria as natural aggregates and at the same time have lower CO_2 footprint and satisfying leaching properties.

Project information

- Supported by Norwegian Research Council through IPN. Project period 2020-2024
- The recycled aggregates that will be developed are produced with dry washing and Re-Con Zero product from Mapei
- The project aims to find optimised CO2 binding and at the same time minimising the leaching

Partnere

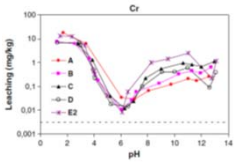
- Mapei Norge (Project leader)
- Ølen Betong, Velde, Norcem, Schwenk Norge
- Agder fylkeskommune
- SINTEF Community (FoU-responsible), University of Agder og Østfoldforskning

SINTEF

38

RECONC – RACS added value

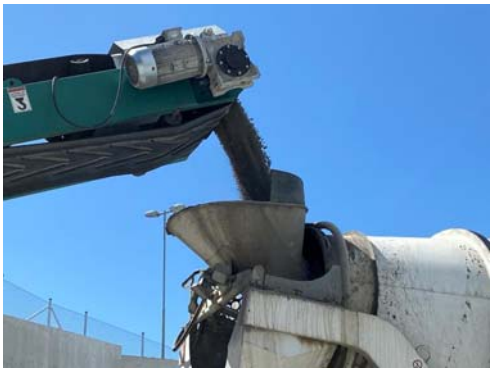
- Capture CO_2 in a thermodynamic stable way faster than the concrete block or as a sludge at landfill
- In a circular material economy it increases the latent CO_2 binding because native binder and RACS absorb CO_2
- The carbonated paste may impose increased pozzolanic reactivity
- Reduce the concrete sludge sent to landfill



SINTEF

39

Resirkulering av betongslam med tørrvaskteknologi



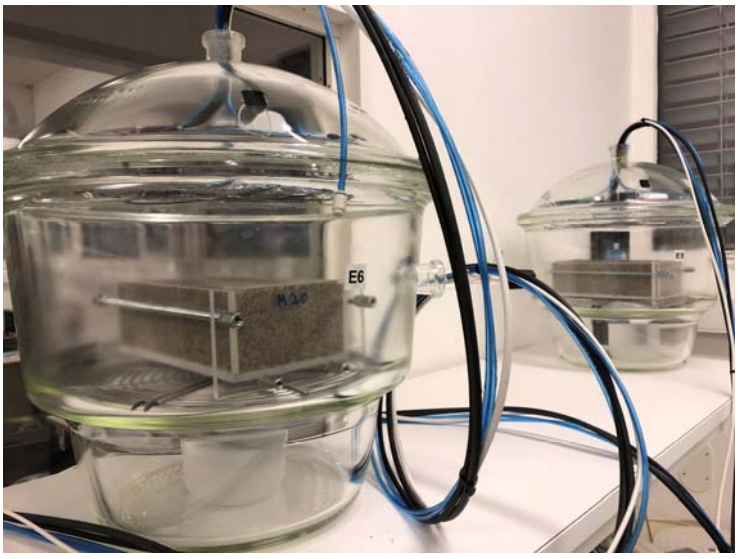
40

SINTEF

Tilslag produsert

SINTEF

Measurement technology established



SINTEF


Hva er karbonatiseringsgraden?

43


First pilot with RACS in road – Fv 3936 and Fv 3940 i Kristiansand
Agder fylkeskommune, Ølen Betong, Velde, Crusher, Mapei
University of Agder and SINTEF

44

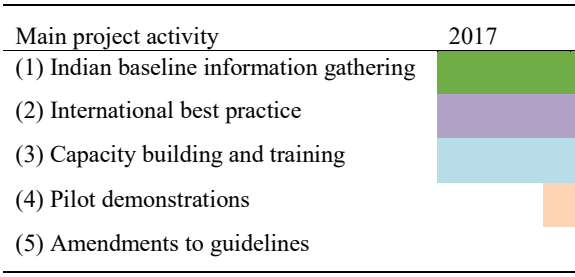
First pilot with RACS in road – Fv 3936 and Fv 3940 i Kristiansand

Agder fylkeskommune, Ølen Betong, Velde, Crusher, Mapei University of Agder and SINTEF

45

Indo-Norwegian cooperation on *"Treatment and recycling of C&D waste in India"*

Overall objective is to increase the treatment and recycling capacity of C&D waste in India

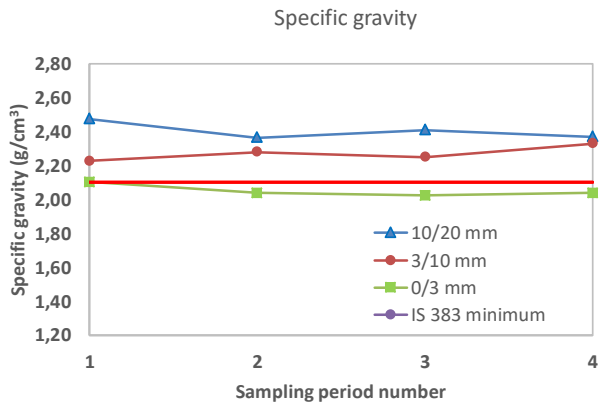


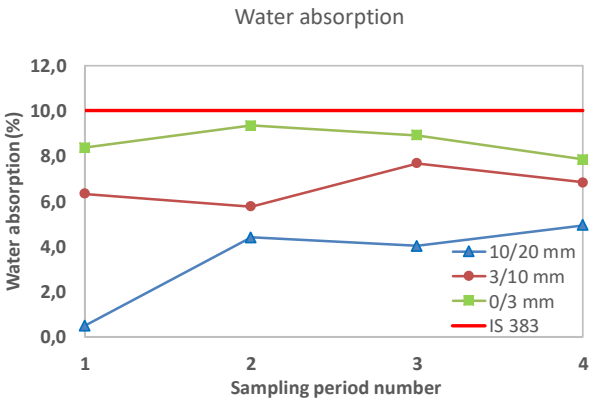
SINTEF

46

47

Specific gravity and water absorbtion

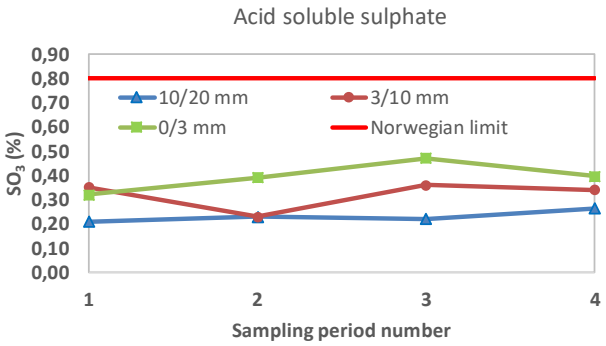


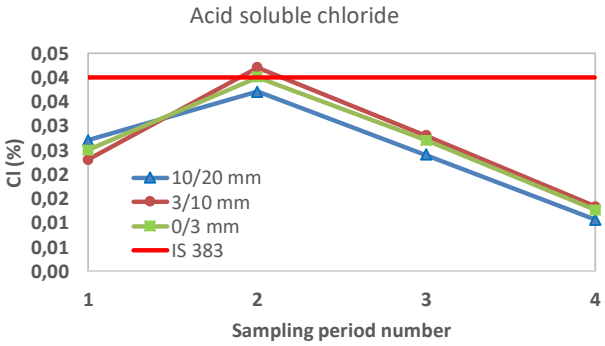


SINTEF

48

Acid soluble sulphate and chloride

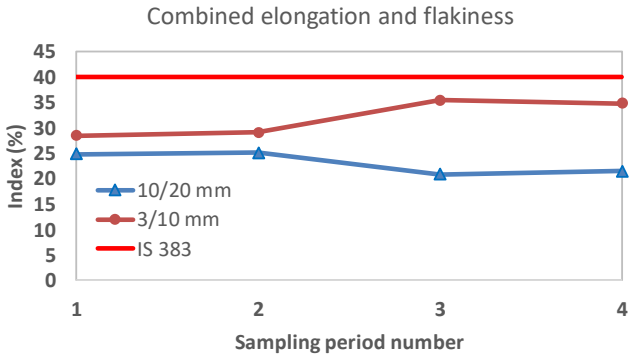


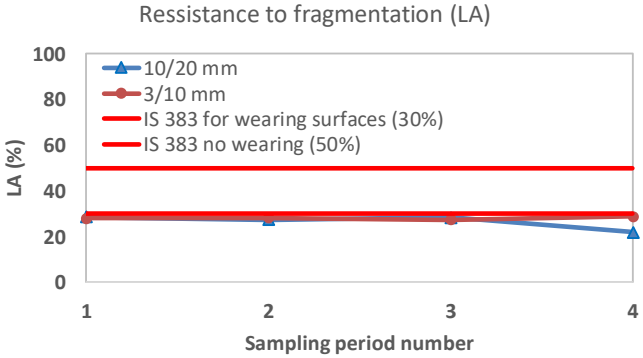


SINTEF

49

Elongation/flakiness index and Los Angeles





SINTEF

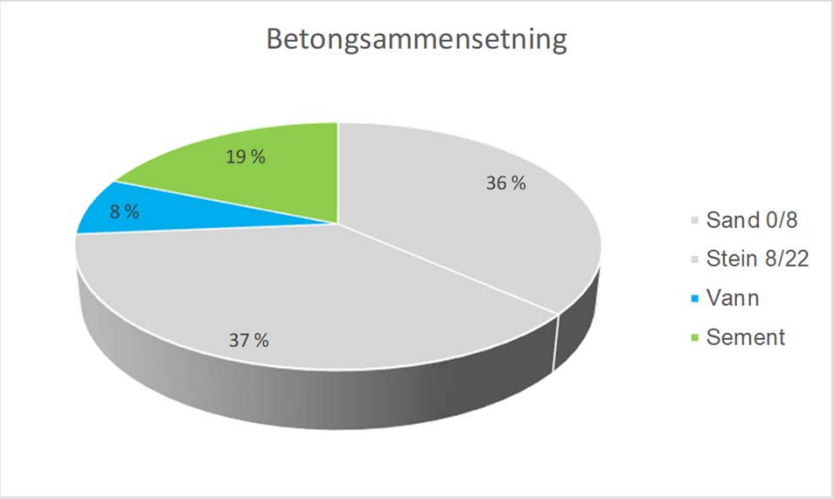
50

How to increase the CO_2-binding capacity for concrete?

SINTEF

51

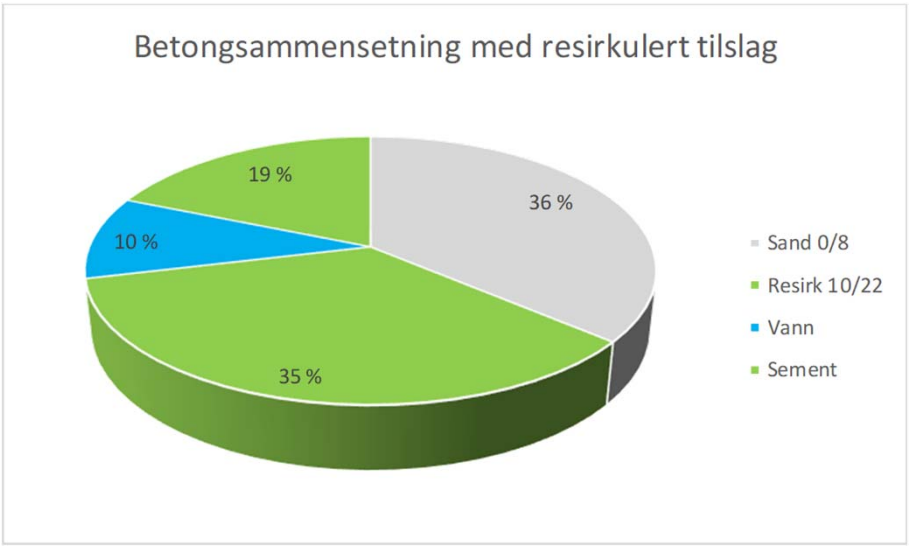
Concrete – cement hydrates that binds CO_2



SINTEF

52

Concrete – cement hydrates that binds CO_2



SINTEF

53

54


Beneficial use: Increased CO_2 - binding capacity
CO_2-R1
Godrej Construction, blocks produced with C&D waste recycling plant, 22/11-2018 Mumbai. Blocks sampled for CO2-binding measurements in SINTEF laboratories in Oslo.

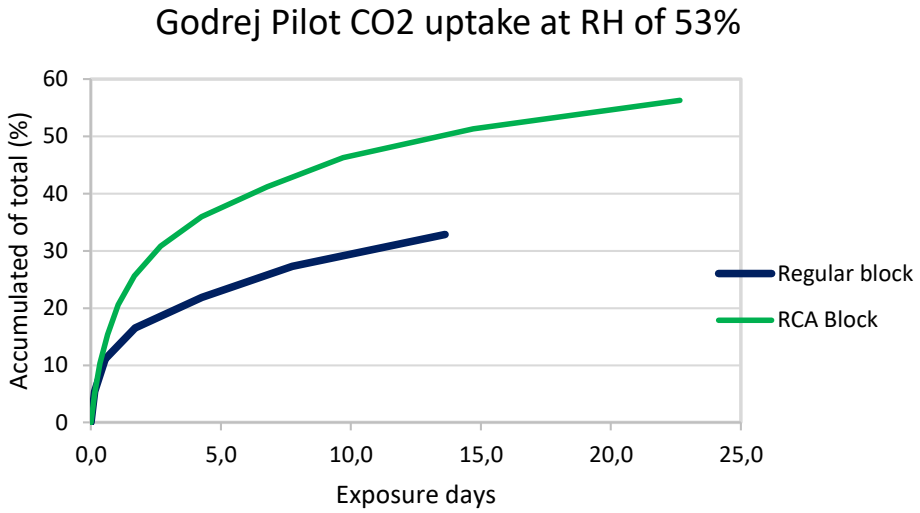
55


CO_2-R1
CO_2-R1

56

57

CO2 – binding – Concrete block with and without RCA



SINTEF

58

Environmental properties – Total concentration and leaching

"Content and leaching"

SINTEF

59

Environmental negative impacts – heavy metals

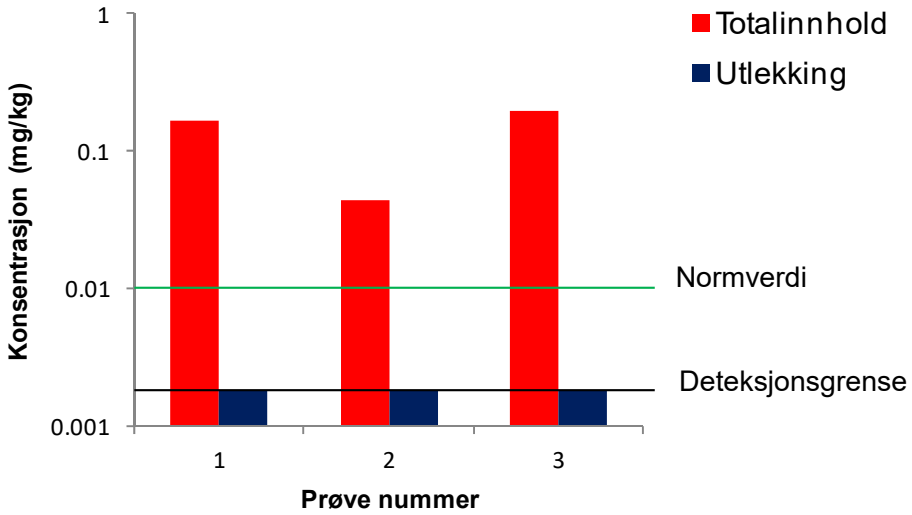
Element	Soil criteria (Norwegian Pollution Act) mg/kg	RESGRAM (results from filter press fraction) mg/kg
As	< 8	< 0,5 – 5,5
Pb	< 60	43 – 86
Cd	< 1,5	< 0,05 – 0,46
Cu	< 100	10 – 90
Cr	< 50	10 – 31
Hg	< 1	0,03 – 0,22
Ni	< 60	9,0 – 23
Zn	< 200	96– 195

What do we do?

SINTEF

60

Why is leaching important: PCB leaching[1]



[1] C.J. Engelsen, H. Justnes, M.N. Malmedal, T. E. Kalbakk, T. S. W. Plessser, Estimation of leaching from C&D waste (concrete rubble) contaminated with PCB and toxic metals, SINTEF Report SBS (2011) F0074 in Norwegian.

SINTEF

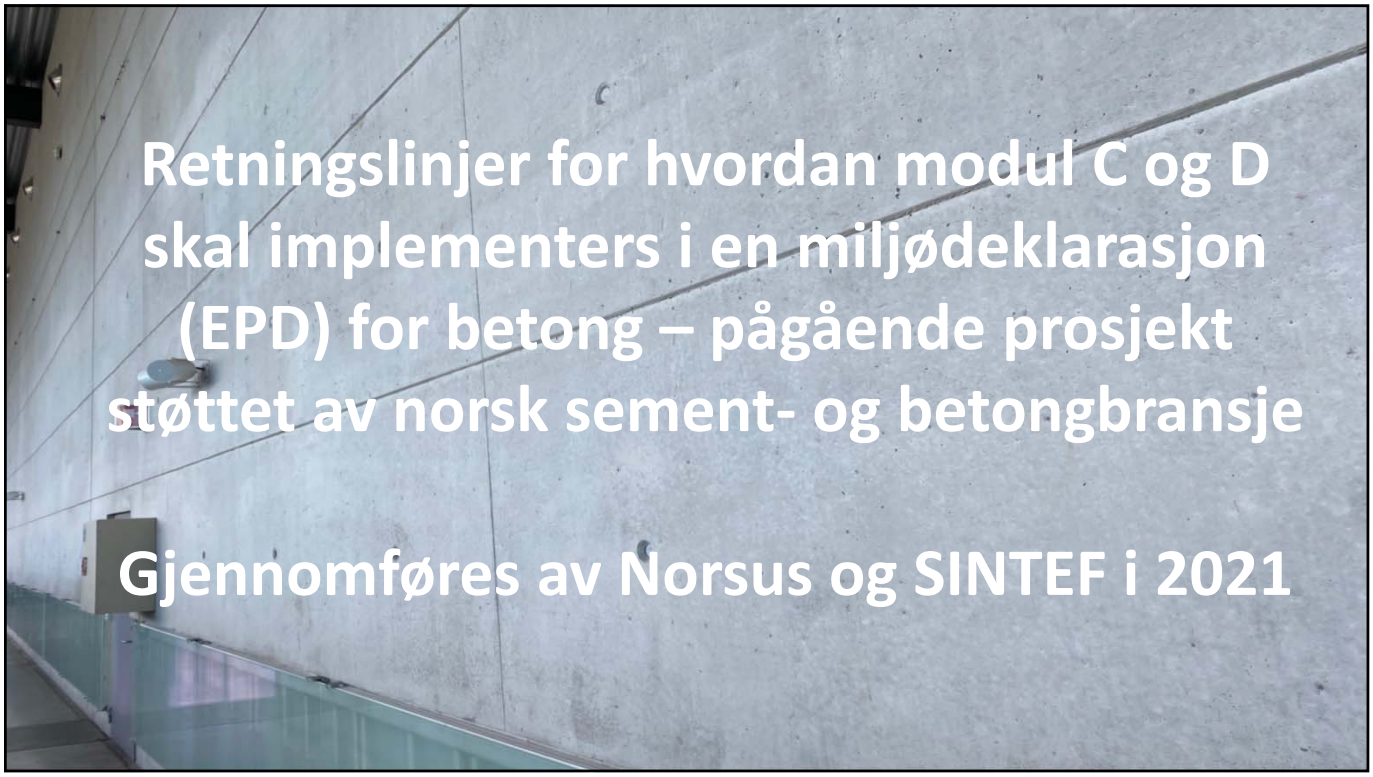
61

Environmental negative impacts – heavy metals

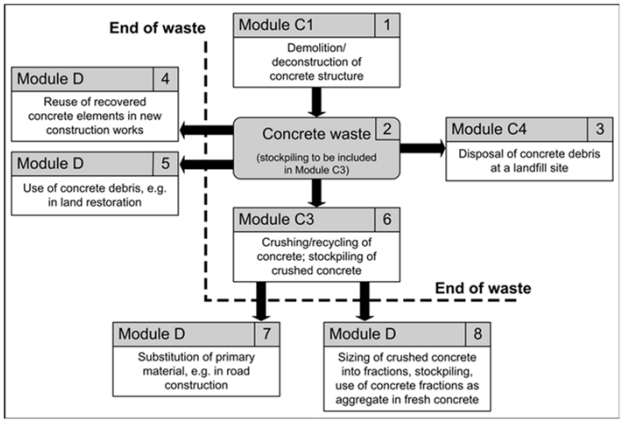
Element	Sub-base[1] (calculated on the basis of actual leaching) mg/kg	Soil criteria (Norwegian Pollution Act) mg/kg	RESGRAM (results from filter press fraction) mg/kg
As	< 20	< 8	< 0,5 – 5,5
Pb	< 200	< 60	43 – 86
Cd	< 3	< 1,5	< 0,05 – 0,46
Cu	< 250	< 100	10 – 90
Cr	< 110	< 50	10 – 31
Hg	< 1	< 1	0,03 – 0,22
Ni	< 110	< 60	9,0 – 23
Zn	< 600	< 200	96– 195

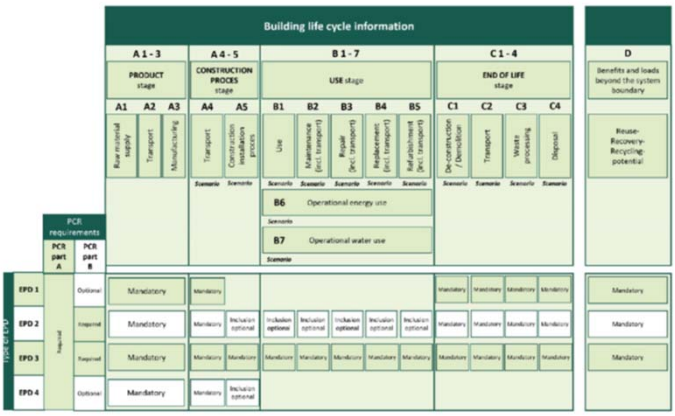
[1] Source: Engelsen, C.J. Recycled aggregates from concrete and masonry, Building Research Design Guides 572.111, SINTEF Byggforsk (2015).

SINTEF



63

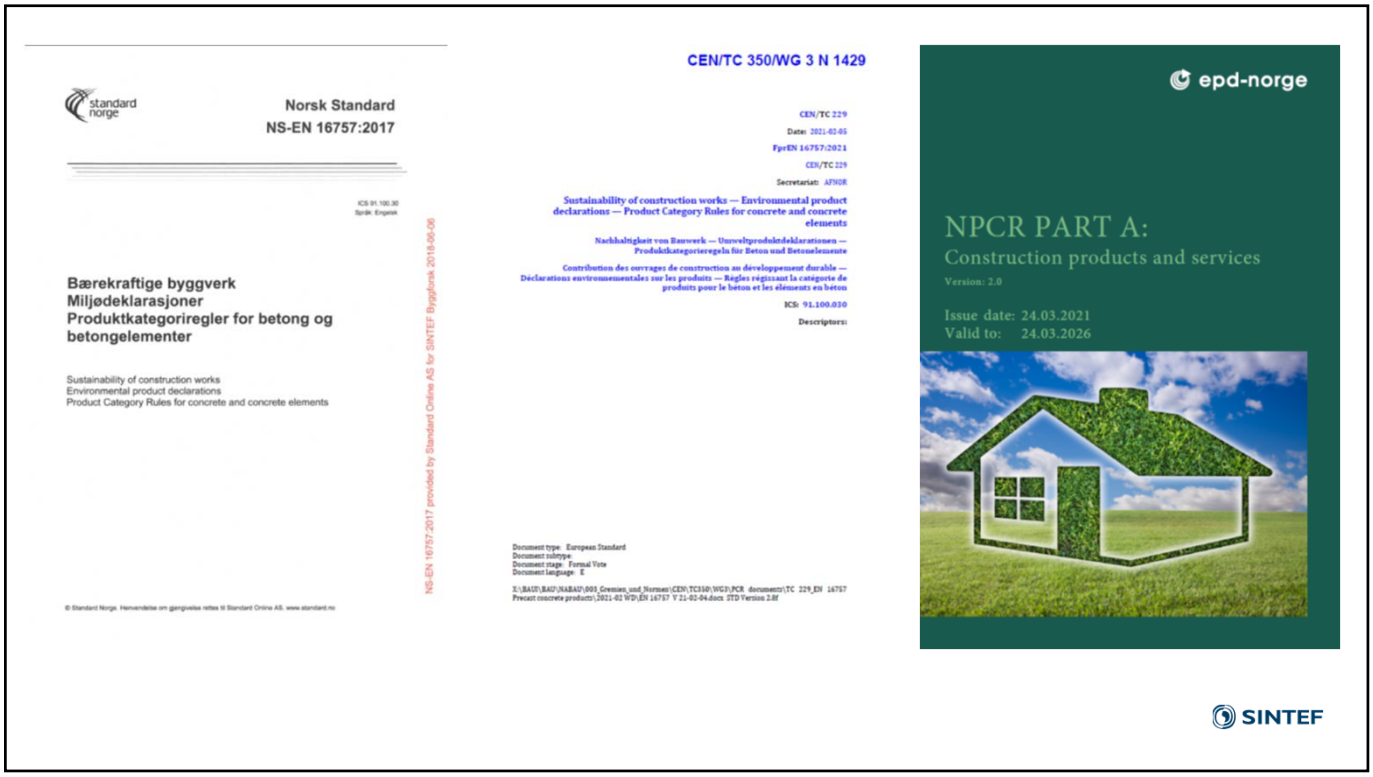




Modul C og D er nå obligatorisk i en EPD

SINTEF

64


standard norge
Norsk Standard
NS-EN 16757:2017
Bærekraftige byggverk
Miljødeklarasjoner
Produktkategoriregler for betong og betongelementer
Sustainability of construction works
Environmental product declarations
Product Category Rules for concrete and concrete elements
CEN/TC 350/WG 3 N 1429
Sustainability of construction works — Environmental product declarations — Product Category Rules for concrete and concrete elements
epd-norge
NPCR PART A:
Construction products and services
Version: 2.0
Issue date: 24.03.2021
Valid to: 24.03.2026
SINTEF

65


Utnyttelse av resirkulert tilslag N200 Vegbygging.
Prosjektet skal gi forslag til ny kravstilling og gi innspill til normaltekst i N200 Veibygging. Det skal utarbeides et forbedret klassifiseringssystem for gjenbruksmaterialer knyttet til betegnelsene i NS-EN 13242.
Prosjektet gjennomføres av SINTEF i 2021

66

What is the remaining challenges and solutions?

1. Producing recycled aggregates with stable quality and predictable durability.
2. Cost efficient declaration/documentation needs to be developed for local conditions.
3. Future concrete will have to apply alternative binders with changed lechabilities which impose challenges during recycling.
4. Breakthrough technologies that decrease water absorption, re-activates the cement paste and increase the strength of the recycled aggregates.
5. Further improvement of the technical standards and classification

SINTEF