DURABILITY OF LOW-CLINKER CONCRETE WITH WATER-REPELLING ADMIXTURES

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20.08.2025

Forskningsrådet IPNÆRINGSLIV21 – 332241 (2022-2025)

BE-sTrONG – Towards the sustainable concrete structures of the future in marine environments

Utilisation of advanced admixtures and environmentally/climate-friendly binders to design and construct concrete structures in marine environments with:

a) significantly reduced CO_2 emissions, and

b) significantly reduced resource requirements for maintenance and repair during the intended service life of the structures.

BE-sTrONG: The concept radically breaks with existing practices for the development of environmentally and climate-friendly solutions that are anchored in current EN and DNV standards.

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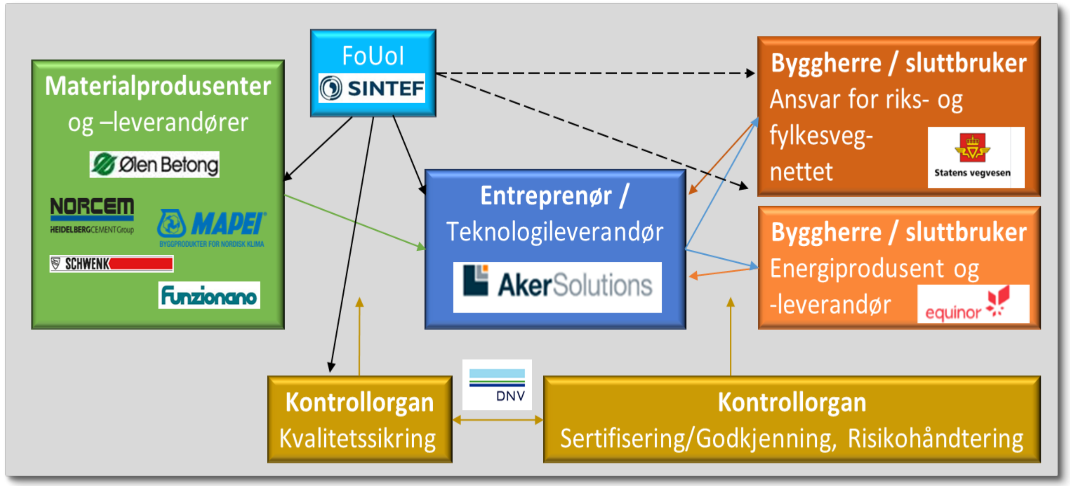
- will adapt advanced material solutions, document critical properties through performance testing and in-situ long-term exposure as well as condition monitoring of prototypes, and document the environmental performance.
- will form the basis for revision of current standards, here DNVGL-ST-C502, which is necessary for the innovation to be realised.



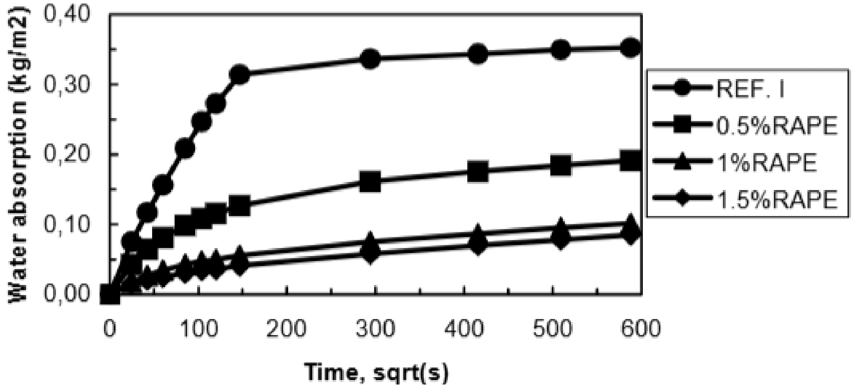
Project owner: Aker Solutions AS
https://prosjektbanken.forskningsradet.no/BE-sTrONG-332241

Project partners: *Aker Solutions AS, Statens Vegvesen, Equinor Energy, DNV AS, Ølen Betong AS, Mapei AS, FUNZIONANO AS, NORCEM AS og SCHWENK Norge AS, SINTEF*

Content

1. Background

H. Justnes et al (2004) *found that v*egetable oils can be used as water-repelling agents for mortars in dosages 0.5-1.5 % of cement weight, if well dispersed while blending in. (see Fig. 2 from the publication)



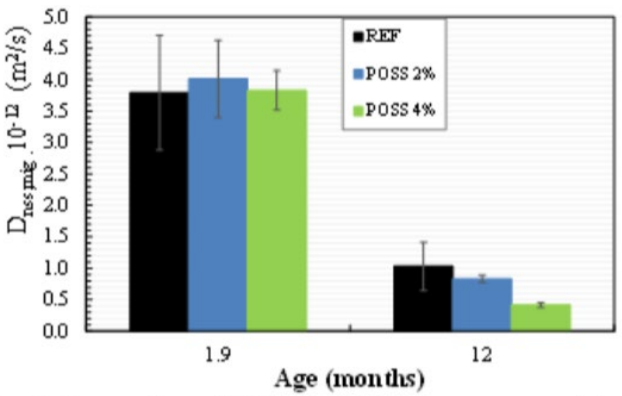


Fig. 4. $D_{app\ mig}$ from NT Build 492 in concretes containing POSS.

Pilz et al (2019) and M.C. Alonso et al (2023) within Lorcenis EU project showed that hydrophobic functionalized **P**olyhedral **O**ligomeric **S**ilse**s**quioxanes (**POSS**) in form of powder improve Cl^- resistance. (see Fig.4. from the publication)

Numerous studies on <u>low-clinker/low CO_2</u> mortars and concretes were performed in 2023/2024 with a) **POSS** in different forms (dry, emulsion/suspesion, coated, pure) and b) release agent based on vegetable/**R**apeseed **O**ils (**RO**).

2. Materials

Mix ID / Materials	*P50*	*S50*	*free water*	*Abs. water*	*Årdal 0/8mm*	*Årdal 8/16mm*	*SP*	*RO*	*POSS*	*AEA*
P50 REF 0.40	418,3		167,3	6,3	1027,8	806,7	2,26			
P50 0.55 RO	341,1		187,6	6,2	1022,5	802,6	0,76	3,42		
P50 0.55 POSS	343,7		189,0	6,2	1002,5	786,9	0,53		12,50	
S50 REF 0.40		416,5	166,6	6,3	1030,8	809,1	2,28			
S50 0.55 RO		337	185,4	6,2	1016,0	797,5	0,67	3,39		
S50 0.55 POSS		343,6	189,0	6,2	1007,8	791,1	0,49		12,49	
P50 REF 0.40 A	410,8		164,3	5,9	965,3	757,7	2,11			1,08
P50 REF 0.55 A	348,9		191,9	6,0	982,8	771,5	0,43			0,42
P50 0.55 RO A	345,9		190,3	6,1	986,6	774,4	0,58	3,46		1,99
S50 REF 0.40 A		414,0	165,6	6,0	973,0	763,7	2,24			0,83
S50 REF 0.55 A		350,6	192,6	6,1	991,5	778,3	0,38			0,45
S50 0.55 RO A		344,8	189,7	6,1	987,8	775,3	1,06	3,45		1,49

2 binders - 50% clinker replacement by:

1) natural volcanic pozzolan (Iceland) – **P50**
2) slag - **S50**

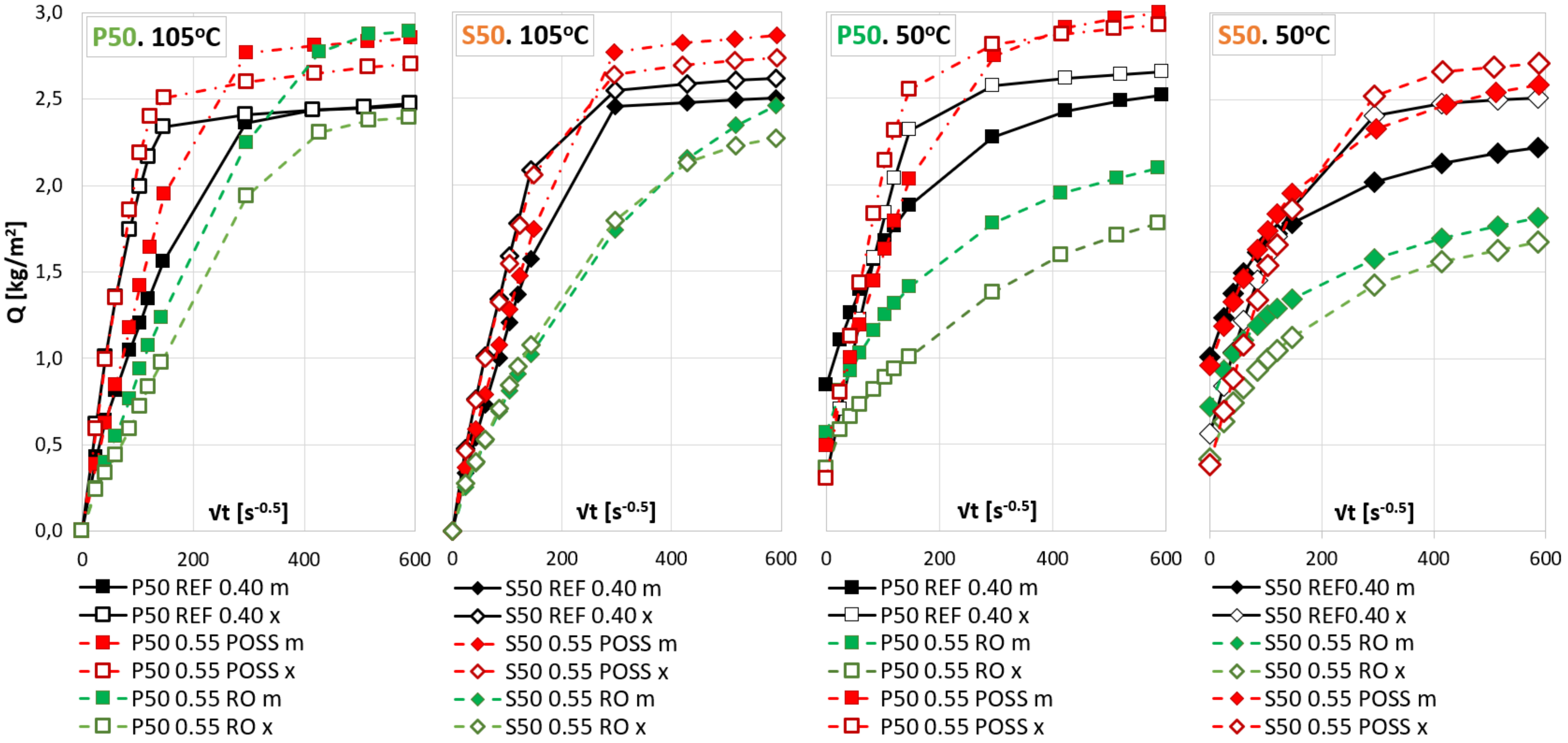
POSS - **P**olyhedral **O**ligomeric **S**ilsesquioxanes as emulsion with 33% dry matter. 1.2% dry matter of binder

RO – release agent based on vegetable/**R**apeseed **O**il. 1% of binder

REF 0.40 – chosen reference w/b-ratio for durable concrete

SP and AEA – superplasticiser Mapei Dynamon SX-23 and air-entraining agent Mapeair 25

3. Capillary absorption



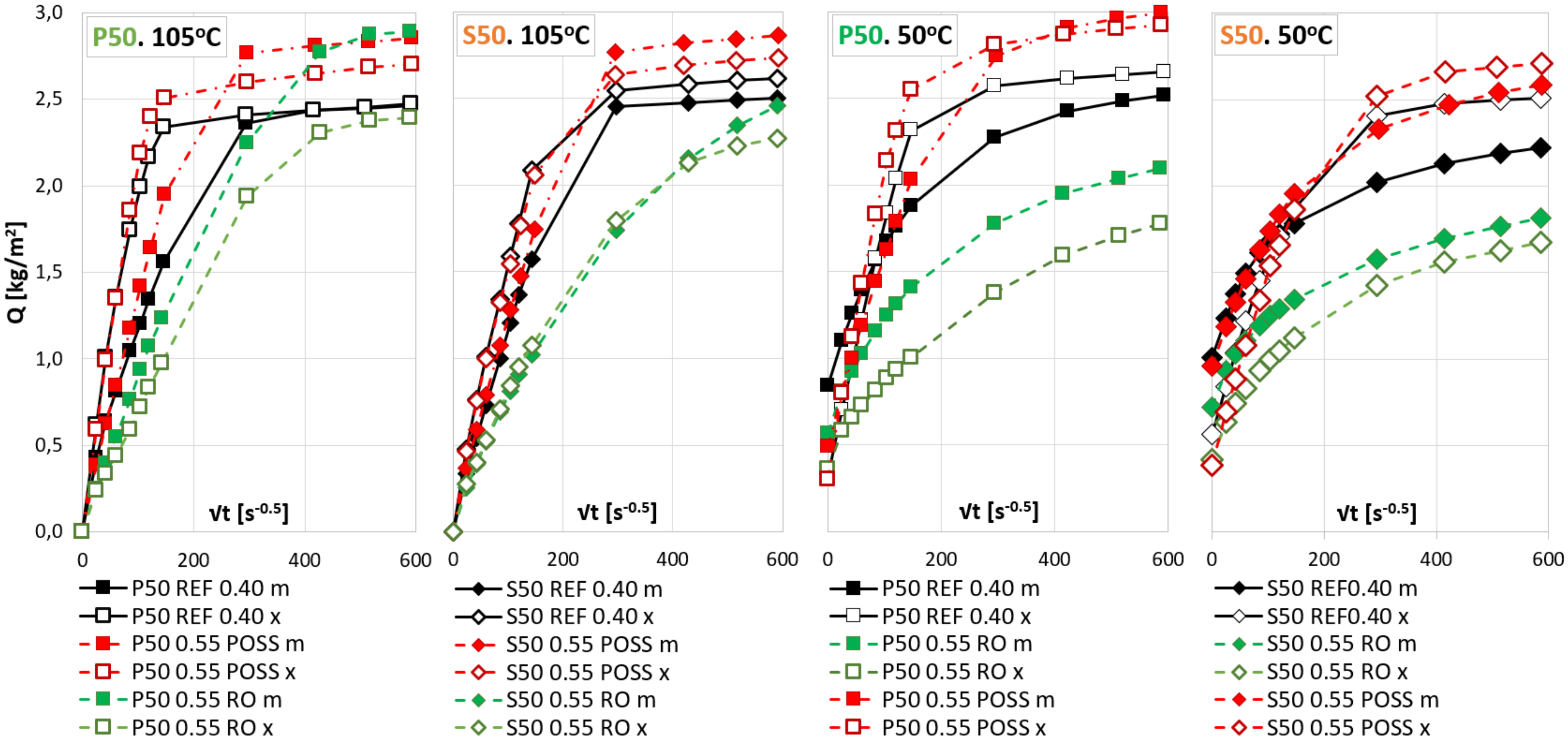
x-samples for early **ex**posure to drying: 1d+6d in water, sawing 20 mm discs, 21d in 50% RH.

m-samples for better **m**aturity: 1d+27d in water, sawing 20 mm discs (standard procedure).

<u>Drying temperatures</u>: 50°C (more realistic microstructure) and 105°C (standard)

Capillary suction results. Top: curves for different pre-conditioning and drying procedures.

3. Capillary absorption



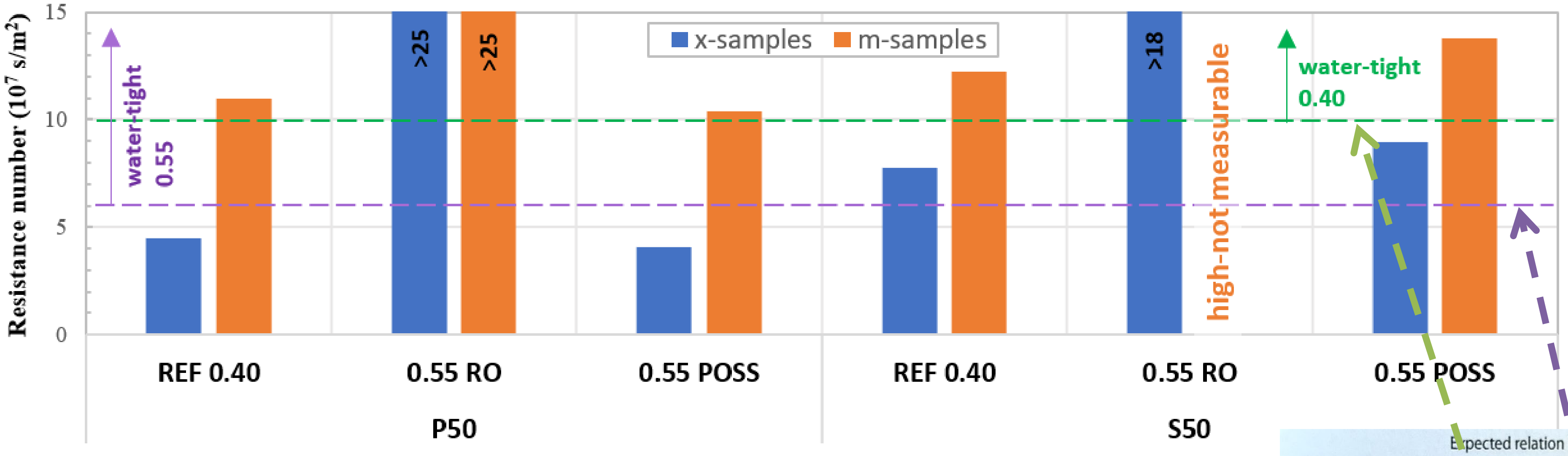
POSS 0.55 curves follow the path for the **REF 0.40** or slightly faster.

All the **RO** curves are considerably lower (**REF 0.40**) with a slower absorption rate.

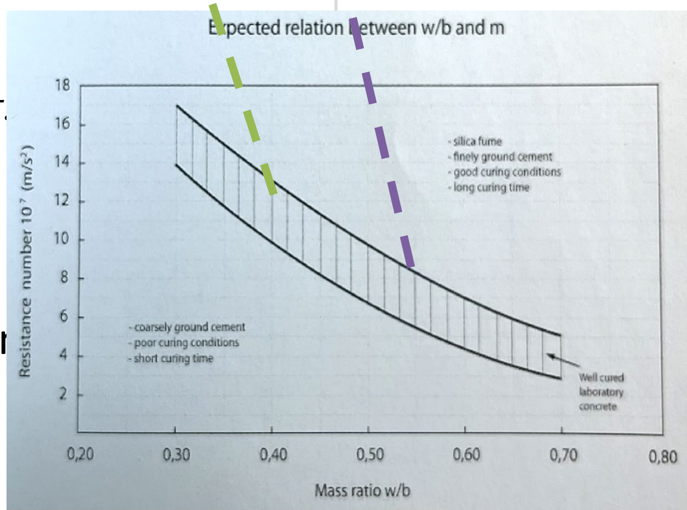
RO is more sensitive to drying temperature (than **POSS**), yet still no clear saturation point, even at 105 °C.

Capillary suction results. Top: curves for different pre-conditioning and drying procedures.

3. Capillary absorption

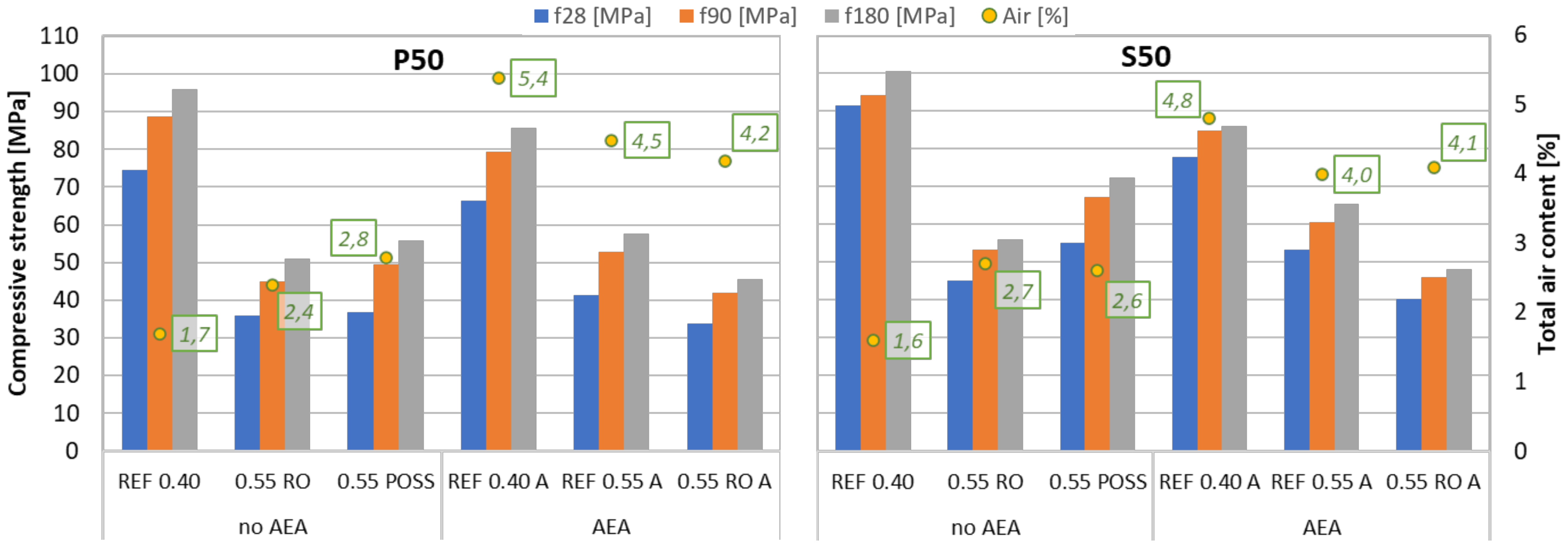


Capillary suction results. Resistance number for 105°C drying.



a) P50 requires prolonged curing for impermeability
b) Both admixtures reduce permeability
c) RO provides superior watertightness compared to REF 0.40, regardless of the precor

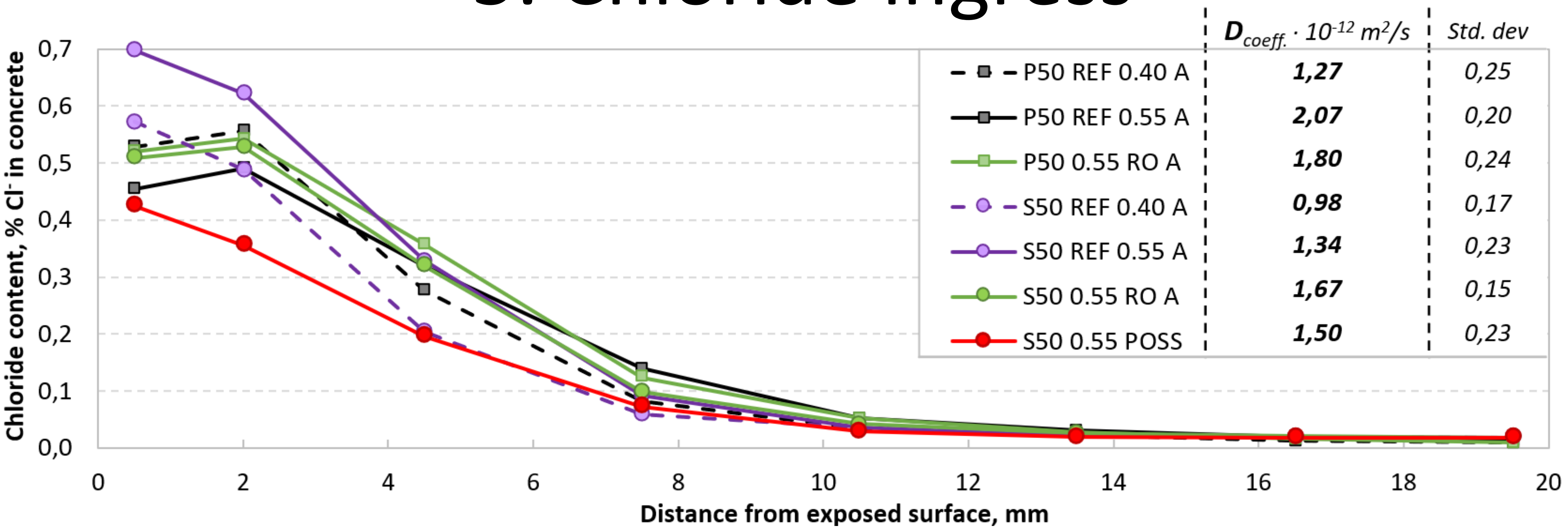
4. Strength



Strength development with and without AEA and air content

a) Strength development from 28 to 180 days is higher for P50 than for S50
b) RO reduces strength by 10-20 % (consistent with H. Justnes et al)
c) POSS increases strength development by 40 %, compared to RO

5. Chloride ingress



Bulk diffusion after 90 d in 6 % NaCl. Chloride profile and diffusion coefficient.

a) Water-repelling admixtures do not impair (compared to the REF) the chloride resistance of concrete after standard testing for low-clinker binders. D_{coeff} $<2{,}5 \cdot 10^{-12} m^2/sec$ (NS-EN 206).

b) Performance of the two admixtures (also blended), either with P50 or S50, is being tested under marine exposure.

c) Further work is needed to address carbonation and frost resistance.

BE-sTrONG - Mot fremtidens bærekraftige betongkonstruksjoner i marine miljøer

Dette innovasjonsprosjektet er finansiert av

Forskningsrådet

IPNÆRINGSLIV21 – 332241
(2022-2025)

Prosjekteier: Aker Solutions AS
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