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Screening of Low Clinker Binders, Compressive Strength and Chloride Ingress

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ABSTRACT

This paper reports an initial screening of potential new binders for concrete with reduced CO₂-emission. Mortars cured saturated for 90 days are compared with regard to a) compressive strength of mortars with similar water-to-binder ratio, and b) chloride ingress in similar design strength mortars exposed to seawater. The reference used was a binder composition typical for a Danish ready mixed concrete for aggressive environments and strength class C35/45. Based on the present investigation and assumptions up to around 15% reduction in CO₂ emission from binder production might be obtained without compromising the 90 days compressive strength and resistance to chloride ingress in marine exposure by using selected alternative binders.

Key words: Cement, chlorides, CO₂-emission, supplementary cementitious materials (SCM)

1. INTRODUCTION

Despite continuous improvements in the cement industry, e.g. [1], the CO₂ emissions has been increasing due to the growth in cement demand in the developing countries, and the share of cement production is now estimated to be around 6-10% of the total anthropogenic greenhouse gases [2].

A recent report on potential, economically viable solutions for a low-CO₂ cement based materials industry identified two main areas delivering substantial additional reductions in global CO₂ emissions related to production and use of cement and concrete: a) increased use of low-CO₂ supplementary cementitious materials (SCMs) as partial replacement of Portland cement clinker and b) more efficient use of Portland cement clinker [2].

In order to create substantial reduction in CO₂ emission, the concrete types with the highest sales volumes should be the target, rather than tailored cements and concretes for special applications. Ready-Mixed Concrete (RMC) has been the main concrete product within the last decade [3], consuming around 50% of the total cement produced in Europe (Fig. 1).

Similar RMC production-to-cement consumption ratios are observed in the Nordic countries, with the exception of Norway where around 70% of the total cement produced is used for RMC. Compared to Finland and Denmark RMC produced in Norway and Sweden generally contains lower additional amounts of siliceous fly ash added at the concrete plant on top of cement. Lower quantities of fly ash added at the concrete plant in Norway and Sweden are due to noticeable greater demand of RMC with the highest strength class (Fig. 2) than in Denmark or Finland, but also because some of the cement types employed in RMC production in Norway already contain large amounts of fly ash on their own (CEM II type). Fig. 2 also shows that the most used strength classes for RMC production in the EU and average of Nordic countries are the intermediates: C25/30 and C30/37 [3].

Particularly in Denmark, most of RMC plants produce different concrete strength classes by mixing CEM I type cements with varying fly ash content (and water-to-binder ratio), consuming around 60-70% of the total Aalborg Portland grey cement production along with other imported cements supplied by non-national producers. The most often manufactured RMC strength class for aggressive environments is C35/45, and the typical concrete is made with a binder composition of 83% of CEM I type cement and 17% of siliceous fly ash.

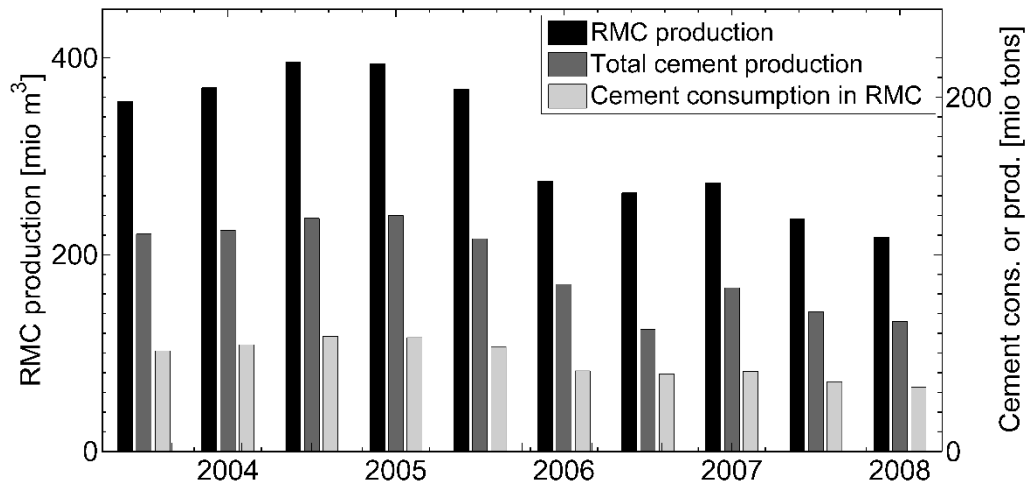


Figure 1 - RMC production (left hand scale); cement consumption and production (right hand scale) in EU from 2004 to 2013 [3].

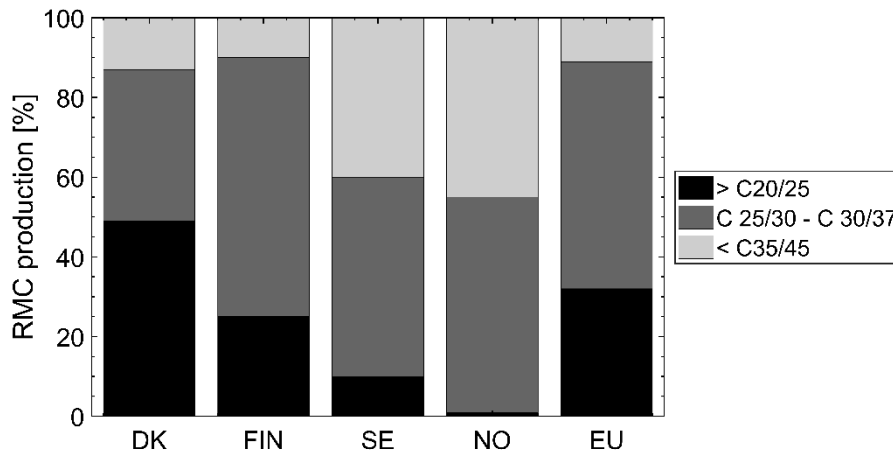


Figure 2 - RMC production by strength class in Nordic countries and EU in 2012 [3].

Regarding possible improvements in cement production, the use of alternative fuels as biomass or waste materials has ecological and economic benefits, such as conserving non-renewable resources. Waste combusted in the cement kiln systems as opposed to dedicated incinerators result in net global reduction in CO₂ emissions and lower CO₂ penalties [4]. However, the use of alternative fuels may result in kiln dust with higher chloride content than other sources. Consequently, the use of kiln dust as limestone filler for production of blended cements type CEM II/A-LL may be constrained by the maximum chloride content in cement (0.10% wt) prescribed in EN 197-1 [5].

Concerning cement and concrete composition, two separate or combined strategies to produce potentially greener concrete by lowering clinker content can be used: partial replacement of the clinker in cement by SCMs according to EN 197-1 [5] and/or partial replacement of the cement in the concrete by mineral additions such as silica fume, siliceous fly ash and/or limestone as described in e.g. the NADs to EN206. The concrete standards differ between countries with regard to the required cement types and strength classes, maximum water-to-cement ratios and minimum cement contents, and the allowed types of mineral additions and cement-to-addition ratios. This introduces large variations in concrete compositions between countries.

This paper reports an initial screening of potential new binders for concrete with reduced CO₂-emission. The objectives of the paper are to compare low clinker binders with regard to

- the compressive strength of mortars with similar water-to-binder ratio
- the chloride ingress in similar strength mortars exposed to seawater
- the CO₂-emission from production of the binders.

The materials investigated include a) a new clinker optimized for facilitating clinker grinding and pozzolanic reactions of supplementary cementitious materials (SCMs) and b) selected SCMs: burnt shale, calcined clay, limestone filler with low and high chloride content, and siliceous fly ash.

2. EXPERIMENTAL

2.1 Constituent materials

The chemical compositions determined by X-ray fluorescence (XRF) of the current clinker (K1), the new highly mineralized clinker (K2) and the other binder constituents are summarized in Table 1. The burnt shale (T) sample was supplied by Eesti Energia AS from Estonia, and the clay (Q) was calcined at FLSmidth as part of another project (“SCM project”). All other materials were supplied by Cementir Holding - Aalborg Portland including two limestone fillers (LL) differing in chloride content and a fly ash (V).

The calculated mineralogical composition of the clinkers and the compressive strength development measured according to EN 197-1 [5] are given in Table 2 and Table 3, respectively.

Table 1 - Chemical composition (%wt), density and Blaine fineness of binder constituents. Two batches of LL with different chloride content were used.

Method	Property	unit	K1	K2	LL	Q	T	V
XRF	SiO ₂	%	20.2	19.5	12.7	62.5	34.2	55.0
XRF	Al ₂ O ₃	%	5.5	6.1	3.6	16.6	8.2	19.9
XRF	Fe ₂ O ₃	%	4.0	3.3	1.8	9.4	4.8	5.5
XRF	CaO	%	65.4	66.0	44.0	0.8	30.1	4.5
XRF	MgO	%	0.80	0.92	0.60	2.95	5.59	1.81
XRF	K ₂ O	%	0.54	0.52	0.58	2.82	4.38	2.16
XRF	Na ₂ O	%	0.21	0.25	0.23	1.95	0.11	1.12
XRF	SO ₃	%	1.5	1.6	0.4	0.4	5.6	0.4
XRF	Cl	%	0.03	0.00	0.21/-	0.03	0.29	0.00
EN 196-2 [6]	LOI	%	0.24	0.47	35	2.39	4.55	3.2
EN 196-6 [7]	Density	kg/m ³	3170	3180	2710	2430	2790	2300
EN 196-6 [7]	Blaine fineness	m ² /kg	390	330	1262	-	432	345
EN 196-6 [7]	20 μm residue	%	-	-	-	10.5	-	-
EN 196-2 [7]	Cl	%	0.02	0.01	0.14/0.48	0.01	0.30	0.02

Table 2 - Mineralogical composition of clinkers (%wt).

Clinker minerals	K1	K2
C ₃ S	65.8	70.1
C ₂ S	8.2	3.1
C ₃ A	7.9	10.4
C ₄ AF	12.1	10.1

Table 3 – Compressive strength development (MPa) of clinkers (+ hemihydrate) measured according to EN 196-1 (normalised to 2% air).

Age (d)	K1		K2	
	Mean	SD	Mean	SD
1	22.0	0.2	-	-
2	32.9	0.3	36.6	0.6
7	50.5	1.4	55.9	1.3
28	64.6	1.4	65.0	1.4
91	-	-	71.8	1.1

The composition of the new clinker was selected to maximize the C₃S content for rapid strength development and rapid release of Ca(OH)₂ to enhance pozzolanic reactions. The optimized C₃S content of the new clinker resulted in an equivalent 28 days strength for a Blaine of 330 m²/kg compared to current clinker ground at fineness around 390 m²/kg. Low fineness of the ground clinker is recommended for manufacturing of blended cements with a high substitution level of finely ground SCMs to reduce water demand and improve workability.

The burnt shale is called CFB and collected at the 1st electrostatic precipitator of Eesti Power plant [8] and contains some phases that may affect the reactions of mortars, such as lime, portlandite, anhydrite, periclase and some clinker phases.

The dried raw clay containing around ¾ by wt. of clay minerals, mainly montmorillonite but also illite, along with other minerals such as quartz, feldspar and phyllosilicates [9], was calcined in a flash calciner [10] at 850°C and subsequently, finely ground to maximize pozzolanic reactivity of calcined clay (Q) within 28 days [9].

Table 4 - Binder compositions in (%wt) and CO₂ emission from binder production. H: hemihydrate; for remaining abbreviations please see the text.

id	K1	K2	H	LL		T	Q	V	SO ₃	Cl	CO ₂ (t/t binder)
				high Cl	low Cl						
R1	76.7		2.6	4.0				16.7	3.30	0.04	0.65
B1		76.5	2.8	4.0				16.7	3.33	0.03	0.65
B2		63.7	2.3		15.8			18.2	2.82	0.03	0.56
B3		63.7	2.3	15.8				18.2	2.82	0.09	0.56
B4		63.7	1.5	7.9		7.9		19.0	2.82	0.07	0.55
B5		63.7	1.1	4.0		11.9		19.4	2.82	0.06	0.55
B6		63.7	2.3		34.0				2.31	0.05	0.58
B7		63.7	2.3	8.5			25.5		2.31	0.05	0.62
B8		63.7	2.3				34.0		2.31	0.01	0.63
B9		58.9	2.2	15.7			15.7	7.5	2.31	0.09	0.56

Binder B1 was used to compare chloride ingress resistance of the new clinker (K2) and the current clinker (K1) in the presence of siliceous fly ash (V), i.e. (B1 vs R1).

The binder compositions given in Table 4 were selected to illustrate the either separate or combined effect of the new clinker, chloride content, SCM type, and clinker replacement on the resistance to chloride ingress and the potential reduction in CO₂ emissions compared to a typical binder composition presently used in ready mixed concrete (RMC) production in Denmark (R1).

Two batches of limestone filler (LL) differing in chloride content (0.14 and 0.48%) were used in binders B2 and B3 to illustrate the potential impact of initial chloride content on chloride ingress. The binder compositions corresponded to cement type CEM II/A-LL for the maximum allowed clinker replacement by limestone filler, i.e. 20% and addition of siliceous fly ash (V) on top to achieve 35% total clinker replacement in binder, both calculated in accordance with EN 197-1 [5] (i.e. omitting CaSO₄). Clinker replacement was calculated similarly for all binders. Table 4 gives the actual clinker replacement.

As shown in Table 4, except for binder B6, the remaining LL-containing binders contain LL with high chloride content. This is to illustrate the potential impact of increased use of alternative fuels for clinker production on the resulting limestone fillers. To meet the requirement to chloride content, $Cl \leq 0.10\%$ according to EN 197-1 [5], binder B6 was prepared with the LL with low chloride content.

Binders B3, B4 and B5 were included to investigate the performance of burnt shale in cement type CEM II/A-M (T-LL). The binders contained 20% of combinations of burnt shale (T) and limestone filler (LL) with three different ratios, expressed as $T/(T+LL) = 0, 0.5$ and 0.75 . Siliceous fly ash (V) was added to achieve 35% clinker replacement in the binder resulting in $(T+V)/(T+V+LL) = 0.53, 0.77$ and 0.89 .

Binders B6, B7 and B8 were included to investigate the performance of cement types CEM II/B-M (Q-LL) without any addition of siliceous fly ash (V), but containing 35% of combinations of calcined clay (Q) and limestone filler (LL) in three different ratios, expressed as $Q/(Q+LL) = 0, 0.75$ and 1 . Binder B9 aimed to show the effect of further clinker reduction (to 60% of binder) by addition of siliceous fly ash (V) to a CEM II/B-M (Q-LL) type cement with 35% clinker replacement and a ratio of $Q/(Q+LL) = 0.5$ resulting in $(Q+V)/(Q+V+LL) = 0.60$.

Finely ground calcium sulphate hemihydrate (hemihydrate, H) with a SO₃ content of 56.3% (measured according to EN 196-2) was included in all binders to control early hydration. The optimum SO₃ content for reference binder (B2) containing only the new clinker (K2) and hemihydrate was determined to 3.5%. The hemihydrate content in other binders was reduced according to the clinker content. For the binders with burnt shale (B4 and B5) the hemihydrate content was further reduced to compensate for SO₃ content of the burnt shale.

The binders were mixed with CEN Standard sand and demineralised water. In addition polycarboxylate ether based superplasticizer (SP), manufactured by BASF with a solid residue of 20% was added to some of the mortars. The density of CEN Standard sand and SP was 2650 kg/m³ and 1100 kg/m³, respectively.

2.2 Series 1, constant w/b

A first series of mortars were mixed and cured according to EN 196-1 [11] (water-to-binder ratios, $w/b=0.5$) to determine compressive strength at 90 days. Although 28 day strength is the most relevant strength parameter for RMC producers at present due to current standards, a curing time of 90 days was selected to enable the SCMs to react further. The mortar compositions are summarized in Table 5. Polycarboxylate ether based superplasticizer (SP) was added to mortars containing either burnt shale or calcined clay in order to achieve similar and comparable flow to R1. Liquid and solid fractions of the SP were considered as part of water and binder, respectively.

Table 5 – Series 1: Composition, flow, air content, and 90 day compressive strength of mortar measured as in accordance with EN 196-1 ($w/b/s=1/2/6$ by mass)

Mortar ID	Binder (g)	SP (g)	Water (g)	Sand (g)	Flow (cm)	Air content (% vol)	90 day strength (MPa)		CO ₂ reduction (%)
							mean	SD	
R1	450.0		225.0	1350	23.3	0.2	73.9	0.9	-
B1	450.0		225.0	1350	22.8	0.9	70.7	2.4	0
B2	450.0		225.0	1350	21.9	1.1	64.8	1.5	15
B3	450.0		225.0	1350	21.7	1.3	66.5	1.1	15
B4	449.9	0.71	224.4	1350	22.7	1.0	70.3	0.7	16
B5	449.8	1.07	224.1	1350	22.9	0.5	70.9	2.2	17
B6	450.0		225.0	1350	20.1	2.7	56.3	1.3	12
B7	449.8	1.15	224.1	1350	20.6	2.1	78.8	2.7	6
B8	449.7	1.53	223.8	1350	20.4	2.7	69.5	0.9	3
B9	449.9	0.53	224.6	1350	20.9	1.8	72.7	1.6	15

The air content of mortars was determined in accordance with [12] on the basis of the density of theoretically air void free mortar and the weight at demoulding. The compressive strength was normalized to an air content of 2 vol % using Bolomey's equation, e.g. [12].

The mortar mixing procedure was amended from EN 196-1 [11] to include one step for a delayed addition of the superplasticizer. Cement and at least 85% of total mixing water were placed into the bowl of a Hobart mixer and mixed for 30 s at the low speed. After these 30 s of mixing, sand was steadily added during the next 30 s and mixing was continued. After 90 s, superplasticizer diluted in remaining mixing water was added to mortar and mixing was continued for an additional 30 s at low speed. Then, mixer was switched to the high speed and mixing lasted for another 30 s. Afterwards, the mixer was stopped for 90 s. During the first 30 s, mortar adhering to the wall and bottom part of the bowl was removed and placed in the middle by means of a rubber scraper. Finally, mixing was continued at high speed for 60 s.

2.3 Series 2, similar 90 day compressive strength

Based on Series 1, new water-to-binder ratios were estimated in accordance with Bolomey's equation [13] to result in 90 day compressive strength equivalent to R1 and constant paste volume. The expected equivalent strengths were, however, not experimentally verified. The compositions of the mortars used for Series 2 are summarized in Table 6. Different dosages of SP were added to mortars in order to achieve comparable flow to the reference (R1). Liquid and solid fractions of the SP were again considered as a part of water and binder, respectively.

The second series of mortars were mixed as Series 1. The mortar samples were cast, cured, exposed and analysed according to procedures reported recently [14]. The mortars were cast in 125 ml plastic bottles (\varnothing 50.5 mm). A small amount of water was added on top of the mortar to ensure saturated conditions. After 90 days curing, approximately 5 mm was cut from the bottom surface and the remaining surfaces were sealed by epoxy. The samples were re-saturated and finally exposed to artificial seawater with a composition according to ASTM D1141-3 [15]. Twelve samples were submerged in 2.5 L. The exposure solution was exchanged after 14 and 28 days and thereafter every 30 days. After 90, 180 and 270 days of exposure, chloride ingress was determined by profile grinding and titration.

Table 6 – Series 2: Mortar compositions (adjusted to same compressive strength; paste/sand = 376/509 by volume) and CO₂ emission from binder production. The calculated CO₂ reductions combine the impact of binder composition and w/b.

id	Binder (g)	SP (g)	Water (g)	Sand (g)	w/b (-)	Cl (%wt)	CO ₂ reduction (%)
R1	450.0		225.0	1350	0.50	0.009	-
B1	452.6		224.5	1350	0.50	0.007	0
B2	464.2	1.02	216.3	1350	0.47	0.007	13
B3	456.8	0.59	219.2	1350	0.48	0.020	14
B4	448.8	0.83	222.0	1350	0.50	0.016	17
B5	451.7	1.35	220.7	1350	0.49	0.013	17
R6	482.9	1.79	213.3	1350	0.44	0.012	6
B7	416.7	0.45	233.1	1350	0.56	0.010	13
B8	434.2	2.37	224.2	1350	0.52	0.002	7
B9	433.6	0.38	226.2	1350	0.52	0.019	18

1.3 CO₂ emission from binder production

The CO₂ emissions per ton of binder (Table 3) were estimated considering hemihydrate, fly ash and burnt shale as CO₂ neutral, i.e. CO₂/t, and assuming 0.85 t CO₂/t of clinker, 0.1 t CO₂/t of limestone filler, and 0.27 t CO₂/t of calcined clay. The CO₂ reductions were calculated considering the CO₂ emissions from each constituent and the w/b variations.

3 RESULTS AND DISCUSSION

3.1 Compressive strength

The 90 day compressive strength of the mortars with w/b=0.5 (Series 1) normalized to the same air content (and thus differing from Table 5) is illustrated in Fig. 3. The compressive strength of the mortars with the two clinkers (R1 vs B1) are comparable, while some of the SCM types or combinations appear to affect the 90 day compressive strength.

As has been reported earlier, a synergistic effect between alumina containing SCMs and limestone filler (LL) exists (e.g. [9,16]). This is illustrated in Fig. 4 for calcined clay (Q). An optimum composition that maximized the compressive strength at 90 days can be observed. The strength

enhancement is attributed to pozzolanic reactions of the calcined clay and synergetic effects between reactive alumina from the clinker and SCM and the CaCO_3 from the limestone filler [9]. For binders with calcined clay (Q) (B7, B8, B9) the performance of B7 is significantly better than the reference (R1). (Note that the clinker content is lower further reduced in B9.) No synergetic effect was observed for burnt shale (T).

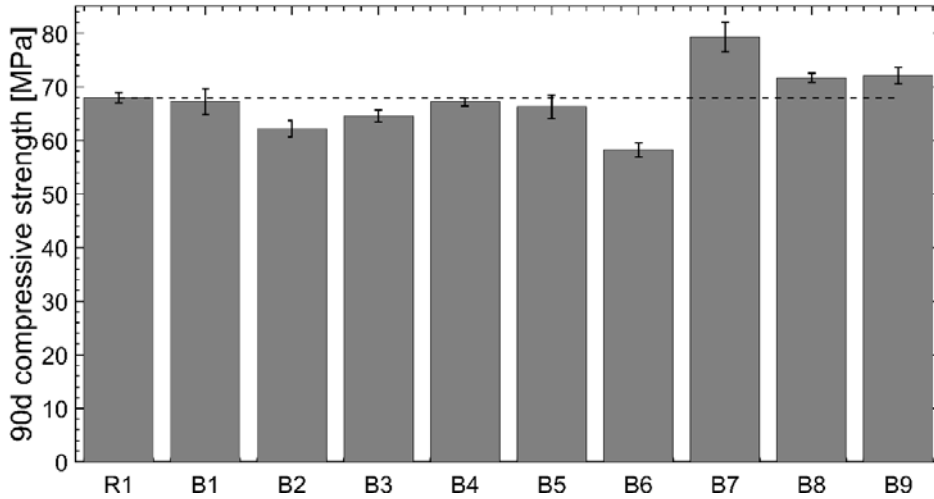


Figure 3 - Series 1: 90 day compressive strength of mortars of ($w/b = 0.5$), normalized to 2% air content. The dotted line compares to the average compressive strength of B1. The error bars indicate \pm SD.

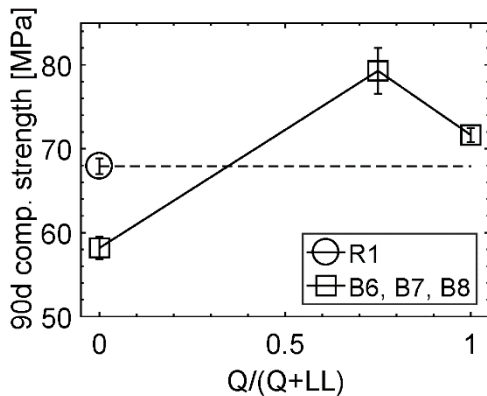


Figure 4 - Synergetic effect between limestone filler (LL) and calcined clay (Q). 90 day compressive strength of mortars of ($w/b = 0.5$), normalized to 2% air content. The error bars indicate \pm SD.

The equivalent performance achieved by B9 with 40% clinker replacement by V, Q and LL compared to B6-B8 with 35% clinker replacement by only Q (B8) or Q and LL (B6-B7), indicates that binders containing only 60% of clinker and higher contents of limestone filler than optimum, may still provide sufficient $\text{Ca}(\text{OH})_2$ and CaCO_3 to enable pozzolanic reaction and synergetic effects between reactive alumina and CaCO_3 .

3.2. Chloride ingress

Chloride ingress profiles after 90, 180 and 270 days exposure to seawater of mortars with comparable 90 days compressive strength are shown in Fig. 5. To allow for possible use of the data, e.g. for verification of models, the measured data are also given in tabular form (Appendix, Table A1 – Table A3). It should be kept in mind that w/b varies between the mortars; from 0.44 (B6) to 0.56 (B7), ref. Table 6.

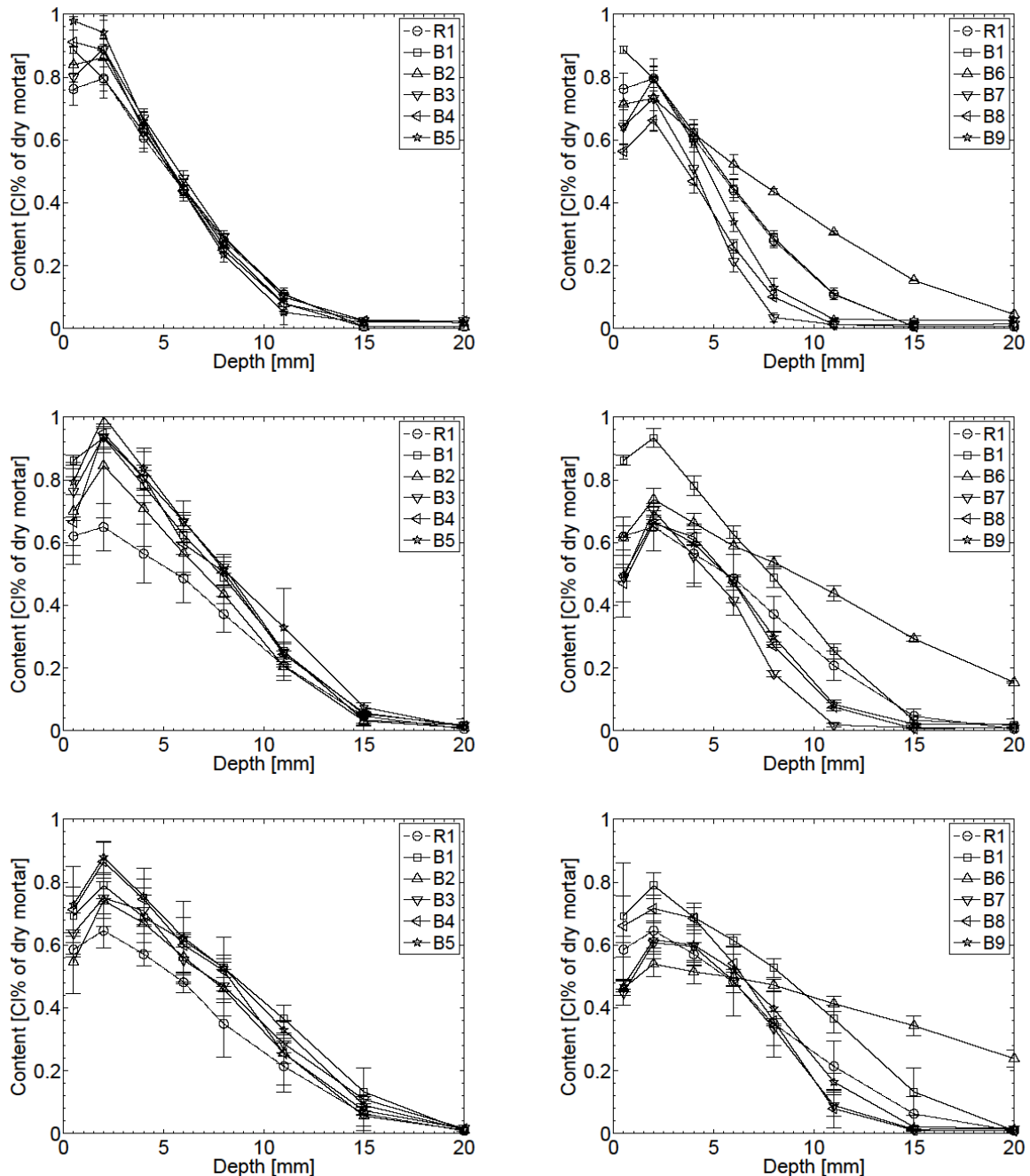


Figure 5 – Chloride profiles after 90 (upper), 180 (middle), and 270 (lower) days exposure to artificial sea water at 20°C. The error bars indicate +/- SD.

The maximum total chloride concentration after 270 days exposure was found at a depth of approximately 2-3 mm for all mortar samples, while a decreased total chloride concentration was observed at the surface. The effect is explained by leaching and other phase changes causing a reduced binding capacity, see e.g. [17,18].

The ingress depths are in general comparable for all binders, except for the binder with 34% limestone filler (B6), which exhibited a very low ingress resistance. Most binders with alternative binder constituents exhibited a higher maximum chloride content, indicating an increased binding capacity compared to the reference blend (R1).

Except at the outer surface, the profiles of mortars with the new and old clinker (B1 vs R1) were similar after 90 days exposure. However, after 180 and 270 days the surface concentration in the mortar with the old clinker (R1) appeared reduced; and, more importantly, the chloride content at deeper depth appeared lower in R1. Furthermore, only mortars with calcined clay (B7-B9) showed lower chloride ingress than the reference mortar (R1). This despite that some of the other mortars had a lower w/b than the reference (R1), see Table 6.

There was no measureable impact of the mortar prepared from the limestone filler with low and high chloride content (B2 vs B3).

The mortars with burnt shale (B4 and B5 vs B3) showed the highest chloride concentrations in the surface near region, indicating the highest binding capacity.

The beneficial impact of calcined clay (B7-B9) is illustrated in Fig. 5 (right). The binding capacity for these blends appeared increased while the ingress depth was decreased, compared to the binder with only limestone filler (B6). The observations are in agreement with recent findings; see e.g. [19]. More importantly, the chloride ingress at deeper depth appeared lower than in the reference (R1) – and in the mortar with the new clinker (B1), which was also used for B7 – B9. The beneficial impact of the calcined clay appears to be diminishing with exposure time.

Except for the mortars with limestone filler (B6), all mortars with high substitution rate by alternative binder constituents showed higher resistance to chloride ingress than the mortar with the same (new) clinker and only 16.7% fly ash (V) (B1) after 180 and 270 days exposure. Comparing 90 days ingress data, where B1-B5 show similar chloride profiles, the data indicate prolonged reaction of the alternative binder constituents in these mortars.

Except for the mortars with calcined clay (B7, B8, B9), which within the period of testing showed highest chloride ingress resistance, all mortars with the new clinker showed lower resistance to chloride ingress than the reference mortar (R1). The results indicate that around 15% reduction in CO₂-emission (Table 6) can be obtained by using alternative binders without compromising the resistance to chloride ingress in marine exposure of mortars with similar design compressive strength at 90 days.

4. CONCLUSIONS

Based on the present investigation and assumptions, up to around 15% reduction in CO₂ emission from binder production might be obtained for selected binders without compromising the 90 days compressive strength and short-term resistance to chloride ingress in marine exposure by using alternative binders instead of a binder composition typical for a Danish ready-mixed concrete for

aggressive environments and strength class C35/45. Due to varying degree of reaction at testing the long-term chloride resistance needs to be documented. Other issues to be considered are e.g. carbonation resistance and conditions for reinforcement corrosion.

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Table A3 – Total chloride content (%wt of dry mortar) after 270 days exposure to artificial sea water. Mean and SD (in brackets).

Depth [mm]	R1	B1	B2	B3	B4	B5	B6	B7	B8	B9
0.5	0.585 (0.022)	0.692 (0.064)	0.546 (0.101)	0.637 (0.065)	0.712 (0.072)	0.728 (0.121)	0.463 (0.023)	0.448 (0.039)	0.661 (0.201)	0.470 (0.020)
2	0.645 (0.054)	0.789 (0.041)	0.741 (0.082)	0.750 (0.064)	0.865 (0.064)	0.880 (0.048)	0.540 (0.039)	0.606 (0.037)	0.716 (0.044)	0.616 (0.061)
4	0.571 (0.037)	0.688 (0.031)	0.669 (0.090)	0.709 (0.074)	0.745 (0.064)	0.755 (0.091)	0.514 (0.037)	0.595 (0.051)	0.685 (0.048)	0.600 (0.064)
6	0.481 (0.033)	0.614 (0.021)	0.561 (0.078)	0.551 (0.075)	0.600 (0.089)	0.623 (0.118)	0.497 (0.026)	0.485 (0.111)	0.541 (0.029)	0.520 (0.052)
8	0.349 (0.105)	0.527 (0.030)	0.459 (0.086)	0.469 (0.054)	0.518 (0.050)	0.526 (0.099)	0.472 (0.017)	0.334 (0.054)	0.358 (0.009)	0.397 (0.054)
11	0.214 (0.081)	0.364 (0.044)	0.256 (0.101)	0.286 (0.029)	0.255 (0.033)	0.330 (0.028)	0.413 (0.024)	0.089 (0.034)	0.078 (0.062)	0.164 (0.027)
15	0.062 (0.055)	0.132 (0.076)	0.055 (0.032)	0.108 (0.014)	0.072 (0.011)	0.090 (0.018)	0.343 (0.031)	0.013 (0.001)	0.010 (0.004)	0.020 (0.001)
20	0.008 (0.007)	0.008 (0.003)	0.010 (0.003)	0.016 (0.001)	0.015 (0.001)	0.012 (0.001)	0.238 (0.027)	0.014 (0.002)	0.008 (0.005)	0.017 (0.001)
26	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.012 (0.001)	0.014 (0.001)	0.000 (0.000)	0.135 (0.015)	0.000 (0.000)	0.000 (0.000)	0.017 (0.000)
36	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.067 (0.008)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)