Going “Green” in concrete

What does that mean in short, medium and long term?

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CEMENT & CONCRETE SA

Agenda:

- Cement Evolution
- Cement misconceptions
- Cement current initiatives
- Cement Future initiatives
- Environmental product declaration (EPD)
- Concrete and specification
- Summary

Cement evolution

- Before introduction of EN 197-1 specification (1971 – 1996)
  - SABS 471:1971: Portland cement (ordinary, rapid-hardening, and sulphate resisting)
  - SABS 831:1971: Portland cement 15 (ordinary and rapid-hardening)
  - SABS 626:1971: Portland blast furnace cement
  - SABS 1466:1988: Portland fly ash cement
- 8 cement types, 2 strength classes (vibrated mortar cubes)
- Max SCM – mainly 15% (Only Portland fly ash cement: 25 – 35% fly ash, and PBFC: 16-70% blast furnace slag)
- Specific Surface Area and Fineness were specified
- Only 3 and 7 days compressive strength were specified (No 28 days)
- Initial setting time was 45 minutes as minimum

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Cement evolution

Introduction of EN 197-1 as SANS 50197-1

They are grouped into three main cement types as follows:

Sulfate resisting Portland cement:

— CEM I-SR 0 Sulfate resisting Portland cement (C_3A content of the clinker = 0 %),

— CEM I-SR 3 Sulfate resisting Portland cement (C_3A content of the clinker ≤ 3 %),

— CEM I-SR 5 Sulfate resisting Portland cement (C_3A content of the clinker ≤ 5 %),

Sulfate resisting blast furnace cement:

— CEM III/B-SR Sulfate resisting blast furnace cement (no requirement on C_3A content of the clinker),

— CEM III/C-SR Sulfate resisting blast furnace cement (no requirement on C_3A content of the clinker),

Sulfate resisting pozzolanic cement:

— CEM IV/A-SR Sulfate resisting pozzolanic cement (C_3A content of the clinker ≤ 9 %),

— CEM IV/B-SR Sulfate resisting pozzolanic cement (C_3A content of the clinker ≤ 9 %).

The composition of each of the seven products in the family of the sulfate resisting common cements shall be in accordance with Table 2. The cement type notation shall be in accordance with the requirements of this standard with additional notation by SR 0, SR 3, SR 5 for CEM I cements and only "SR" for CEM III and IV cements.

Table 2 — The seven products in the family of sulfate resisting common cements

Main types	Notation of the seven products (types of sulfate resisting common cement)		Composition (percentage by mass[a])				
			Main constituents				Minor additional constituents
			Clinker K	Blast furnace slag S	Pozzolana natural P	Siliceous fly ash V	
CEM I	Sulfate resisting Portland cement	CEM I-SR 0 CEM I-SR 3 CEM I-SR 5	95 – 100				0 – 5
CEM III	Sulfate resisting blast furnace cement	CEM III/B-SR	20 – 34	66 – 80	-	-	0 – 5
		CEM III/C-SR	5 – 19	81 – 95	-	-	0 – 5
CEM IV	Sulfate[b] resisting pozzolanic cement	CEM IV/A-SR	65 – 79		⟸ --- 21 – 35 --- ⟹		0 – 5
		CEM IV/B-SR	45 – 64		⟸ --- 36 – 55 --- ⟹		0 – 5

[a] The values in the table refer to the sum of the main and minor additional constituents.

[b] In sulfate resisting pozzolanic cements, types CEM IV/A-SR and CEM IV/B-SR, the main constituents other than clinker shall be declared by designation of the cement (for examples, see Clause 8).

Table 1 — The 27 products in the family of common cements

Main types	Notation of the 27 products (types of common cement)		Composition (percentage by mass[a])										
			Main constituents										Minor additional constituents
			Clinker	Blast-furnace slag	Silica fume	Pozzolana		Fly ash		Burnt shale	Limestone		
						natural	natural calcined	siliceous	calca-reous				
			K	S	D[b]	P	Q	V	W	T	L	LL	
CEM I	Portland cement	CEM I	95-100	–	–	–	–	–	–	–	–	–	0-5
CEM II	Portland-slag cement	CEM II/A-S	80-94	6-20	–	–	–	–	–	–	–	–	0-5
		CEM II/B-S	65-79	21-35	–	–	–	–	–	–	–	–	0-5
	Portland-silica fume cement	CEM II/A-D	90-94	–	6-10	–	–	–	–	–	–	–	0-5
	Portland-pozzolana cement	CEM II/A-P	80-94	–	–	6-20	–	–	–	–	–	–	0-5
		CEM II/B-P	65-79	–	–	21-35	–	–	–	–	–	–	0-5
		CEM II/A-Q	80-94	–	–	–	6-20	–	–	–	–	–	0-5
		CEM II/B-Q	65-79	–	–	–	21-35	–	–	–	–	–	0-5
	Portland-fly ash cement	CEM II/A-V	80-94	–	–	–	–	6-20	–	–	–	–	0-5
		CEM II/B-V	65-79	–	–	–	–	21-35	–	–	–	–	0-5
		CEM II/A-W	80-94	–	–	–	–	–	6-20	–	–	–	0-5
		CEM II/B-W	65-79	–	–	–	–	–	21-35	–	–	–	0-5
	Portland-burnt shale cement	CEM II/A-T	80-94	–	–	–	–	–	–	6-20	–	–	0-5
		CEM II/B-T	65-79	–	–	–	–	–	–	21-35	–	–	0-5
	Portland-limestone cement	CEM II/A-L	80-94	–	–	–	–	–	–	–	6-20	–	0-5
		CEM II/B-L	65-79	–	–	–	–	–	–	–	21-35	–	0-5
		CEM II/A-LL	80-94	–	–	–	–	–	–	–	–	6-20	0-5
		CEM II/B-LL	65-79	–	–	–	–	–	–	–	–	21-35	0-5
	Portland-composite cement[c]	CEM II/A-M	80-88	← 12-20 →									0-5
		CEM II/B-M	65-79	← 21-35 →									
CEM III	Blast furnace cement	CEM III/A	35-64	36-65	–	–	–	–	–	–	–	–	0-5
		CEM III/B	20-34	66-80	–	–	–	–	–	–	–	–	0-5
		CEM III/C	5-19	81-95	–	–	–	–	–	–	–	–	0-5
CEM IV	Pozzolanic cement[c]	CEM IV/A	65-89	–	← 11-35 →					–	–	–	0-5
		CEM IV/B	45-64	–	← 36-55 →					–	–	–	0-5
CEM V	Composite cement[c]	CEM V/A	40-64	18-30	–	← 18-30 →			–	–	–	–	0-5
		CEM V/B	20-38	31-49	–	← 31-49 →			–	–	–	–	0-5

[a] The values in the table refer to the sum of the main and minor additional constituents.

[b] The proportion of silica fume is limited to 10 %.

[c] In Portland-composite cements CEM II/A-M and CEM II/B-M, in pozzolanic cements CEM IV/A and CEM IV/B and in composite cements CEM V/A and CEM V/B the main constituents other than clinker shall be declared by designation of the cement (for examples, see Clause 8).

Cement evolution

Introduction of EN 197-1 as SANS 50197-1

Table 3 — Mechanical and physical requirements given as characteristic values

Strength class	Compressive strength MPa				Initial setting time	Soundness (expansion)
	Early strength		Standard strength			
	2 days	7 days	28 days		min	mm
32,5 L[a]	-	≥ 12,0	≥ 32,5	≤ 52,5	≥ 75	≤ 10
32,5 N	-	≥ 16,0				
32,5 R	≥ 10,0	-				
42,5 L[a]	-	≥16,0	≥ 42,5	≤ 62,5	≥ 60	
42,5 N	≥ 10,0	-				
42,5 R	≥ 20,0	-				
52,5 L[a]	≥ 10,0	-	≥ 52,5	-	≥ 45	
52,5 N	≥ 20,0	-				
52,5 R	≥ 30,0	-				

a Strength class only defined for CEM III cements.

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Cement evolution

Introduction of EN 197-5:2011 as SANS 50197-5(Soon, Hopefully)

Table 1 — Portland-composite cement CEM II/C-M and Composite cement CEM VI

Main types	Notation of the products (types of cement)		Composition (percentage by mass a)										
			Main constituents										Minor additional constituents
			Clinker	Blast-furnace slag	Silica fume	Pozzolana natural	Pozzolana natural calcined	Fly ash siliceous	Fly ash calcareous	Burnt shale	Limestone		
	Type name	Type notation	K	S	D [b]	P	Q	V	W	T	L [c]	LL [c]	
CEM II	Portland-composite cement [d]	CEM II/ C-M	50-64	<---- 36-50 ---->									0-5
CEM VI	Composite cement	CEM VI (S-P)	35-49	31-59	–	6-20	–	–	–	–	–	–	0-5
		CEM VI (S-V)	35-49	31-59	–	–	–	6-20	–	–	–	–	0-5
		CEM VI (S-L)	35-49	31-59	–	–	–	–	–	–	6-20	–	0-5
		CEM VI (S-LL)	35-49	31-59	–	–	–	–	–	–	–	6-20	0-5

a The values in the table refer to the sum of the main and minor additional constituents.

b In case of the use of silica fume, the proportion of silica fume is limited to 6-10 % by mass.

c In case of the use of limestone, the proportion of limestone (sum of L, LL) is limited to 6-20 % by mass.

d The number of main constituents other than clinker is limited to two and these main constituents shall be declared by designation of the cement (for examples, see Clause 6).

- Calcite clay
- Can currently be manufactured under SANS 50197-1
- 40-70% Kaolinite are ideal for LC³
- Clays are calcined at 750-850°c – Lower CO2 emissions and older equipment not suited for cement can be used

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Cement Misconceptions:

- Customer A:They are unable to use a cement with high fly ash content I will have problems with delayed setting.
  - A cement that's designed for high fly ash content will have reduced gypsum content
  - 3rd Party blended cement use an existing cement and blend fly ash and slag with to make a new cement so they can not regulate setting as a manufacturer can. They can play with chlorides in order to reduce it though
- Customer B: Refuse to use a CEM IV/B-V 42,5N for concrete, because it has a range of 36-55% fly ash and 5% minor constituents in it. It will be too variable.
  - The standard requires suppliers to do statistical analysis over 1 year period, so if you have a variable patch you have to carry those results for 1 year.
  - If we manufacture such variable cement we will not have customers that are willing to purchase it, thus it is in our best interest to produce consistently.
- Customer C: Requires a cement with R, in order for it to set quicker
- The L, N and R refer to early age strength gain not the setting.
  - Setting is regulated by the gypsum addition.

Cement Misconceptions:

- Customer D:Requires a CEM I 52,5N (OPC) for my construction project for I need to add fly ash to 30% on site a CEM II/A-V 52,5N cement already has some fly ash and thus it will not activate my additional fly ash like a CEM I would.
  - Remember a CEM I is also allowed 5% minor constituents that's allowed and which does not need to be declared.
  - The type of clinker composition, activators and SSA.
  - Example: the CEM I 52,5R from Lafarge does not activate fly ash as well as our CEM II/A-V52,5N does – they use the same clinker but we use different activators.

Cement Current Initiatives:

- Clinker
  - More reactive clinker to activate supplementary cementitious material better
  - Better activators fit for purpose (Early strength, late strength or fly ash activation)
- Fuel
  - Coal Duff – or waste coal that would go to dumps
  - Tires and/or Sludges from other processes with decent calorific values. Care should be taken as some of the material could add sulphates or iron to the raw mix
- Cements
  - LC3 cement – calcined clays
  - Ultra fine and treated slags for cements for use in precast CEM III/A 52,5R (36%+ slag) (Europe)

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Cement Future Initiatives:

- Carbon capture
  - Can be utilized in fertilizers - Spain is working with a pilot project
  - Capturing CO_2 and storing it in recycled aggregates amounting to aggregates with -25% CO_2 footprint. – France ran a pilot plant in 2020
  - CO_2 cured precast units – USA pilot plant operational also tested in France
- Cements
  - Super sulphated slag cement – low early age strength gain – shortage of slag (50-120kg/t)
  - Alkali activated slags (100-250kg/t)
  - Low water concrete binders (170-300kg/t)
- Additives and Accelerators
  - Calcium Silicate Hydrates in liquid for early stage precast activation
  - New generation activators working on different phases of cement clinker
- Moving towards net zero integrated value Chain
  - Piloted in Austria – Carbon2ProductAustria

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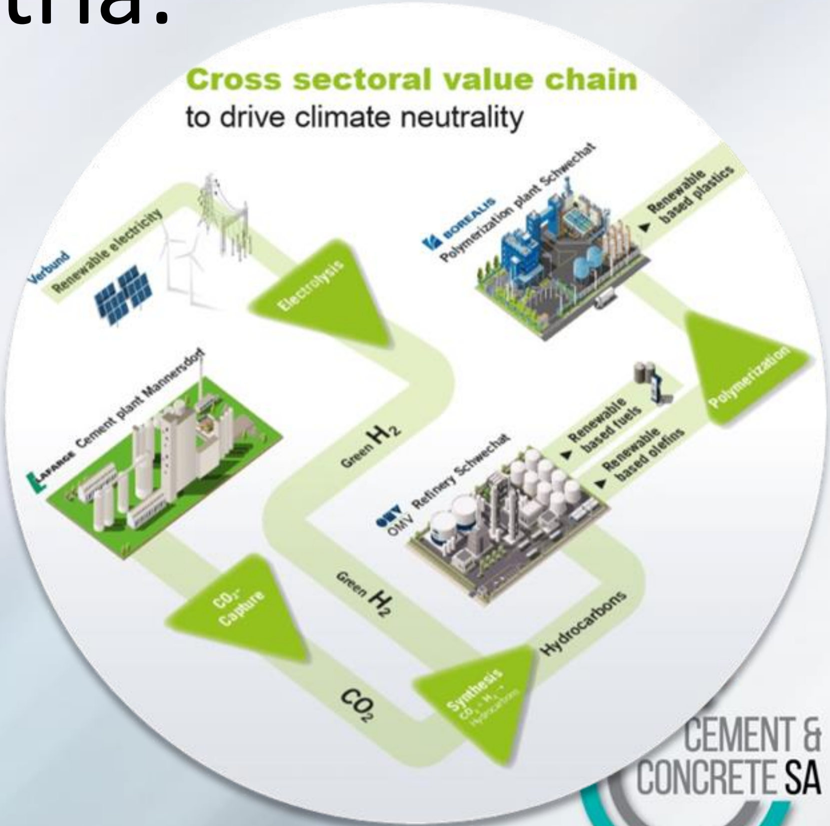
Carbon2ProductAustria:

- 4 leading companies: Holcim, OMV, VERBUND and Borealis
- Joining forces to accelerate towards a Zero CO2 Economy
- Joint planning & construction of a full-scale plant to capture almost 100% of the annual emitted 700,000 t of CO2
- Cross - industry collaboration, establishing a cross-sectoral value chain for carbon capture
- Objective: use the captured CO2 as a resource and process it into synthetic fuels, plastics or other chemicals



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Environmental Product Declaration (EPD):

The Holcim Group drives green initiatives for cement (EcoPlanet) and RMC (EcoPact) through the same principles as how EPD's are calculated. I will give some examples of both and how transport of raw materials can make a product "green" or not.

Carbon washing – is when the full supply chain are not taken into account and thus lower carbon contents are stated.

Example of carbon washing would be if Lafarge South Africa import Clinker for our Richards bay grinding station from Pakistan and the other raw materials from RSA. Now we claim that we make the "greenest" cement for we don't emit CO2 in RSA and we only take the transport of local raw materials into account.

We all stay on the Earth so doesn't matter where we emit the CO2's it effects us all.

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Environmental Product Declaration (EPD): Cement

I have 2 cement factories, one in Lichtenburg and one Cape Town. In both of them I make CEM IV/B-V42,5N cements with 36% fly ash. Both Plants get Fly Ash from Lethabo and Coal from Middleburg area. Both products are transported with Rail and we assume the other raw materials and plants are identical.

	Lichtenburg	Cape Town
Clinker	60%	60%
Fly Ash	36%	36%
Gypsum	4%	4%
Fly Ash Transport (km)	250	1400
Coal Transport (km)	210	1500
kg CO2/t clinker	734	1020

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Environmental Product Declaration (EPD): RMC

I have 2 RMC plants one in Gauteng and one in Cape Town they both use a CEM I 52,5N and have fly ash from Lethabo. We assume the aggregates are Identical.

Raw material	CO2/t	km travel	Mass/ GP	Mass/ CT
CEM I 52,5N	850	100	210	210
Fly Ash	0	100	90	
Fly Ash	0	1400		90
20mm Stone	12,3	100	1000	1000
Crusher sand	12,3	100	716	716
Filler Sand	4,5	100	285	285
Water			180	180
CO2/m3			241	261

8,3% increase in CO_2

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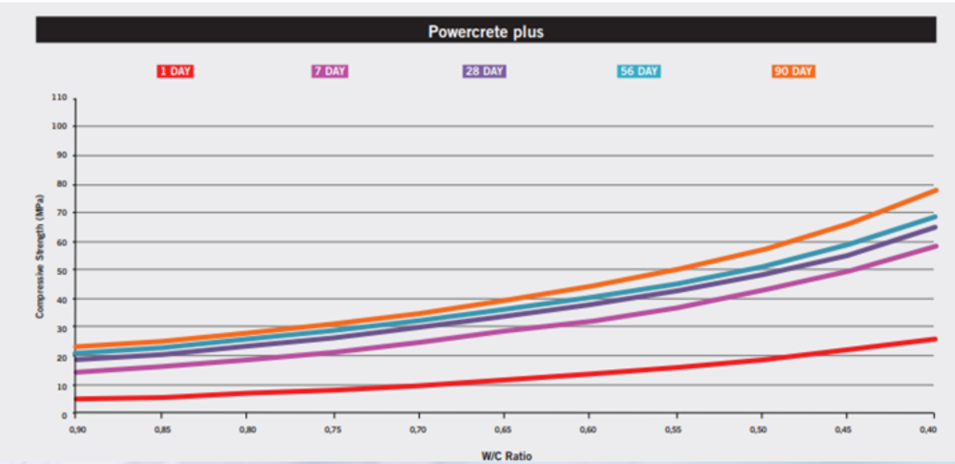
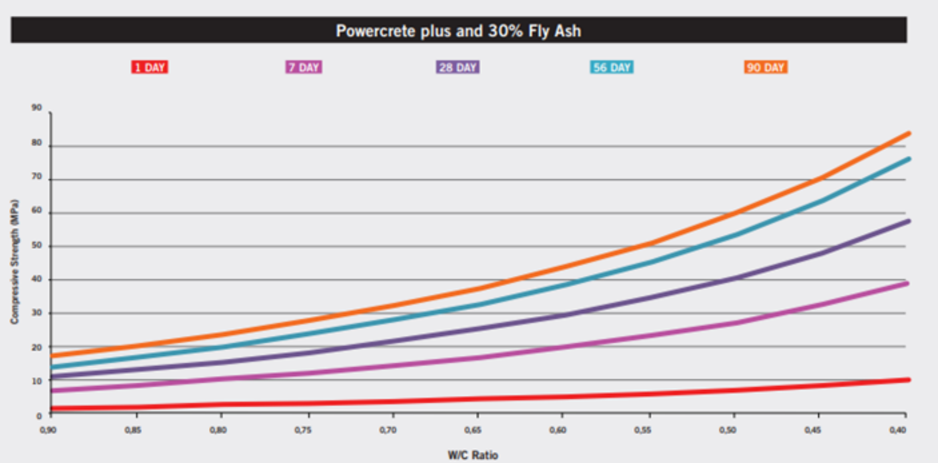
Concrete and specifications:

Why do we need to design for 28 days if we only plan to load the structure at 90 days? What is the cost and environmental effect?

Some people are concerned that we will not get a lot more strength after 28 days.





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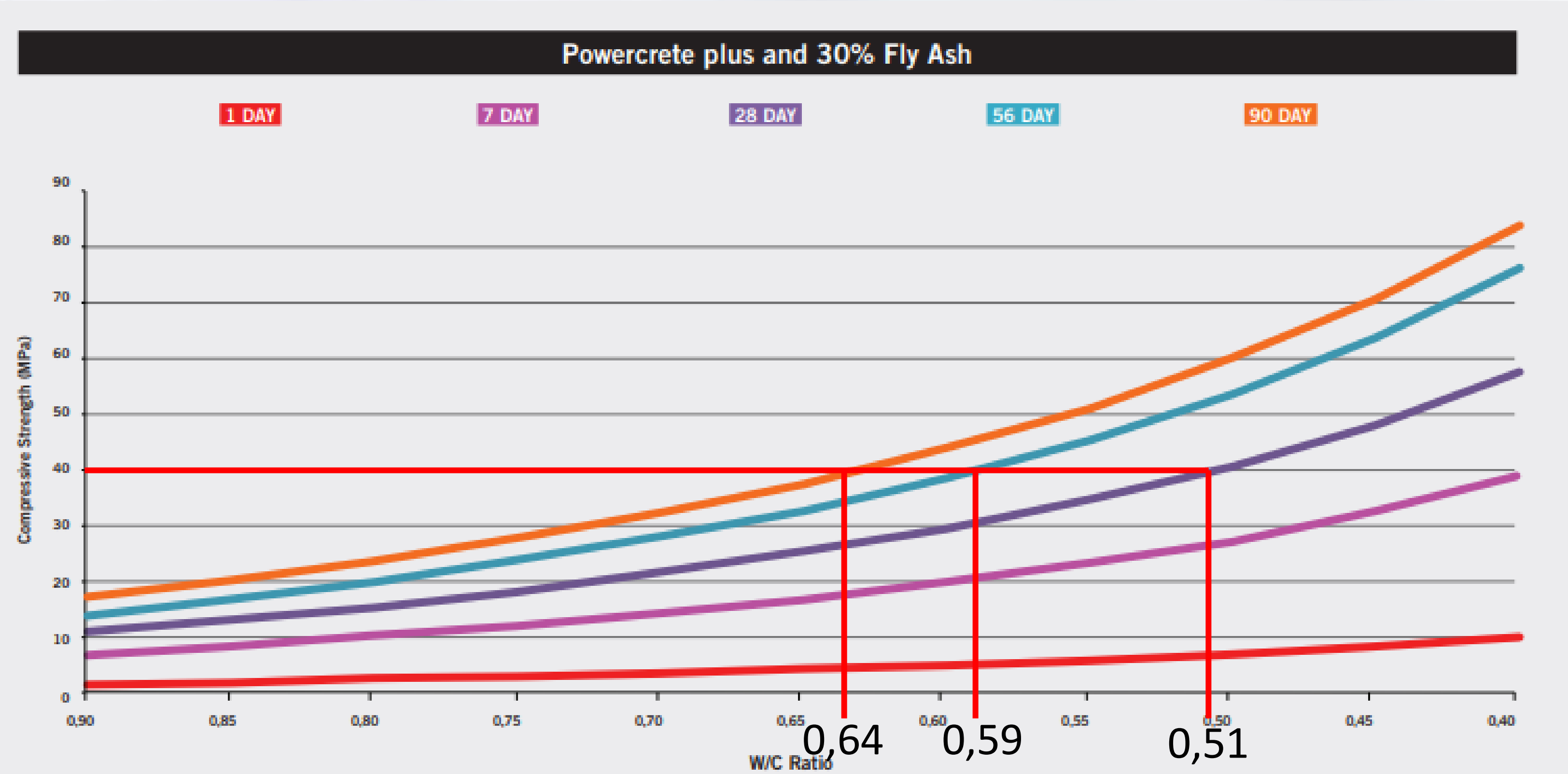
Concrete and specifications:

Let’s use CEM II/A-V 52,5N cement with additional 30% fly ash as an example for 40MPa:



Concrete and specifications:

Raw material	CO_2/t	km travel	R/t	28 day mix	56 day mix	90 day mix
W/C ratio				0,51	0,59	0,64
CEM II/A-V 52,5N	850	100	R1 500,00	247	214	197
Fly Ash	0	100	R400,00	106	92	84
20mm Stone	12,3	100	R200,00	1000	1000	1000
Crusher sand	12,3	100	R200,00	666	702	720
Filler Sand	4,5	100	R150,00	265	280	287
Water				180	180	180
CO_2/m3				271	243	230
R/m3				R786,01	R739,31	R716,06
% reduction on CO_2					10,33%	15,13%
R/m3 reduction					R46,70	R69,96

- Thus by designing for later age there are significant cost savings financially and environmentally.
- There will be technical advantages
- There will however need to be given more thought to planning the project

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Summary:

Cement:

- In the short term there there are no solutions to move away from clinker
- We can utilize higher extended cements, the standard has them available. We need to apply the newer knowledge on cement and not work with what worked in the 80-90's. (Please don't copy and paste, rather spend some time to do a new spec for your project).
- Medium term we will be able to reduce CO_2 by working smarter with the technologies that we have and understand.
- New technologies will take longer to filter down into RSA due to the bad economic state of our country – (some options are expensive)

CO_2 - EPD:

- Make sure that the full value chain is taken into account when emabarking on such a project

Summary:

Concrete:

- Consider where your raw materials are situated
- Consider using more reactive cements that can activate supplementary cementitious material better.
- Consider designing at later ages when your project allows for it.

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Questions:

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