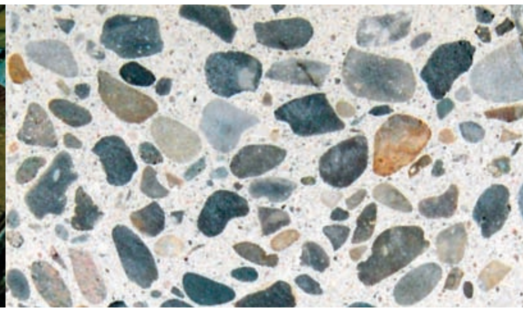
Self Compacting Concrete Based on AALBORG WHITE®





White Self Compacting Concrete
- the concrete for the future

Self Compacting Concrete - or SCC - is the concrete material for the future. With a reduced impact on the working environment due to lack of vibration and the ability to fill more complex and heavily reinforced form sections than with conventional concrete due to self-flowing capabilities, SCC is the next step in concrete evolution.

Successful use of SCC however requires knowledge of this new concrete material - its strengths and weaknesses, possibilities and limitations. With **AALBORG WHITE®**, know-how on white SCC makes it possible to combine easy production with beautiful white or brightly coloured structures.

1. Conversion of existing SCC mixes to AALBORG WHITE®

Many producers of pre-cast elements and ready-mixed concrete have already opted for SCC, but may have focussed on grey cement based SCC.

In that case, the easiest way to introduce white SCC is to convert an existing satisfactory grey SCC concrete mix design to a similar **AALBORG WHITE®** based SCC. The conversion procedure is based on general guidelines obtained from trial conversions from several grey cement types. Therefore, the initial mix design adjustment should not be expected to produce an optimum SCC composition in the first try. Flow spread and air content must be chosen to fit the application of the SCC.

Step-by-step conversion from grey to AALBORG WHITE®

1. Initial adjustment

   Adjust a satisfactory SCC mix based on grey cement as follows:

- Replace the grey cement with **AALBORG WHITE®** at a 1:1 ratio
- Reduce water content by 5%
- Reduce super plasticizer dosage by 25%
- Reduce air entrainment agent dosage with 50% (based on app. 6% air in the original mix. If no air is used, it should be added)
- If necessary concerning colour requirements, use a sand with lighter colour.

2. Trial batching

   Conduct a small trial batching and perform the following tests (use normal SCC mixing sequence):

- Measure flow spread (without drop table). The flow spread should be measured at the time after mixing where the SCC is normally cast (for pre-cast typically within 5 minutes after mixing, for ready-mixed concrete at any time up until one hour, depending on transport duration). Evaluate segregation tendency visually.
- Measure air content in the fresh concrete - it should be between 5 and 7% to attain optimal performance of the white SCC.
- Cast a 150/300 mm cylinder, 150/150 mm cube or similar sample for segregation testing; the sample is allowed to harden (1 day maturity), then cut lengthwise, and the distance from the 10 topmost stones to the surface is measured. This distance divided by (the total height of the sample) multiplied by 100 is the separation in %. Below app. 1%, the separation is normally insignificant to practical use.

3. Adjustment

- If the flow spread or air content is unsatisfactory, or segregation above app. 1% is detected, adjust the mix - see Table 1 for appropriate adjustments - and repeat step 2, trial batching.

4. Verification

- When the mix performs satisfactorily, conduct a full scale trial production with the mix, including any other relevant testing such as strength, freeze/thaw testing, etc.

Visual evaluation

The flow spread measurement gives a first indication on whether there is segregation or not – but this should always be verified by the segregation calculation to make sure.

Figure 1: SCC samples based on AALBORG WHITE®*.*

Left: unadjusted mix (1:1 replacement of grey cement with AALBORG WHITE®*),*

right: same mix, after adjustment. Note the difference in segregation along the edges

Segregation calculation

The 150/300 mm cylinders, cubes or other sample is cut in two lengthwise and the topmost 10 stones are identified.

The distance from the top of the stones to the surface is measured and the average calculated.

This average distance divided by the total height and multiplied by 100 is the segregation in %.

Figure 2: SCC samples based on AALBORG WHITE®*. Left: unadjusted mix (1:1 replacement of grey cement with* AALBORG WHITE®*), right: same mix, after adjustment. Images of final flow spread shown above. Segregation calculated according to the procedure is respectively 3.2% and 0.7% for the two samples.*

Table 1: Mix adjustments depending on observed properties of the SCC mix

Flow spread	Air content	Segregation	Adjustment
Too low	<< 5%	No / Yes	Increase air content 5 - 7% and add water to reach desired flow spread
Too low	>> 7%	No	Reduce air content to 5 - 7%
Too low	5 - 7%	No	Increase water content to achieve desired flow spread
Too low	5 - 7%	Yes	Increase content of fines in the aggregate grading curve and/or adjust paste content
Too high	<< 5%	No / Yes	Increase air content to 5 - 7%
Too high	>> 7%	No / Yes	Decrease aur content to 5 - 7% and decrease superplasticiser dosage and/or water content to reach desired flow spread
Too high	5 - 7%	No / Yes	Decrease superplasticiser dosage and/or water content to reach desired flow spread
Satisfactory	<< 5%	Yes	Increase air content to 5 - 7%
Satisfactory	<< 5%	No	Accept the mix as it is, or increase air content to 5 - 7% and then increase water content to reach desired flow spread
Satisfactory	>> 7%	Yes	Increase content of fines in the aggregate grading curve and/or adjust paste content. Reduce air content to 5 - 7%
Satisfactory	>> 7%	No	Either accept high air content or adjust air to 5 - 7% and increase water content slightly
Satisfactory	5 - 7%	Yes	Decrease super plasticizer content slightly, and increase water content until desired flow spread is achieved

The guidelines above provide a mix yielding the desired flow spread without segregation. However, the mix may flow slightly slower than the original grey counterpart, due to the reduced water content.

For verification, please note that certain super plasticizers have better compatibility with AALBORG WHITE® than others. Improved performance may therefore be obtained if different types are used. Especially flow spread retention with time may vary, dependent on the super plasticizer type. Please note that some super plastizers are air entraining.

If adjustment according to this procedure fails, it may help to switch to the mixing sequence described in section 2.

AALBORG WHITE®

2. Designing AALBORG WHITE® based SCC from conventional mixes

If the producer has no prior experience with SCC, any existing conventional high slump mix can be used as outset for developing one. The primary concern is that the aggregate particle size distribution is optimised for maximum particle packing.

Under these conditions, the general guidelines can be used to produce an initial SCC mix. This SCC mix can then be evaluated according to the procedure described in section 1, and adjusted according to the guidelines in Table 1 until the desired behaviour is reached. Flow spread and air content must be chosen to fit the application of the SCC.

General guidelines:

Powder content

Powder content: High powder content is not in itself a necessary element in the proportioning of an SCC mix. Depending on the aggregates, 350 kg cement pr. m^3 or less is sufficient to produce satisfactory SCC, as long as sufficient paste is present to fill the space between the aggregate particles.

Water/powder ratio

Laboratory tests have shown that a water/powder ratio of app. 0.40 is optimal for AALBORG WHITE® based SCC's. Higher water contents appear to increase the risk of segregation, lower water contents increases the required super plasticizer dosage, which makes the mix less easy to control (the less water there is in the mix, the more important minor variations in water content becomes for the behaviour of the mix.).

Super plasticizer content

Use as much water relative to super plasticizer as possible to obtain the desired flow spread. Excessive super plasticizer contents reduce the flow spread retention of the mix. Also, as already mentioned, a mix containing more water is less sensitive to minor variations in water contents.

Air content

Laboratory tests on several different mixes have shown that the optimal air content for AALBORG WHITE® based SCC is between 5 and 7 %. Air contents around 4-5 % result in fast-flowing SCC with high final flow spread. They can sustain prolonged mixing (as in a mixing truck delivering ready-mixed concrete) with little tendency to foam, but also has decreased robustness regarding variations in water contents. Air contents around 7-8 % result in slow-flowing SCC with low final flow spread. They have increased robustness regarding variations in water content, but a high tendency to foam when subjected to prolonged mixing.

Mixing sequence[1]

The following mixing sequences have proven robust in the sense that the same air content and flow behaviour is obtained every time with the same set of materials when used. They have been used for laboratory batching of several types of mixes, including varying cement types, additives and aggregate types with good results. Mixing time can be substantially reduced when more efficient industrial mixers are used. Try the short sequence first, and if that fails try the longer but more robust. Mix for 30 seconds for each step.

Short sequence

- Pre-mix the aggregates
- Add **AALBORG WHITE®** (and fillers, if any) and water.
- Add air entrainment agent
- Add super plasticizer

Long sequence

- Pre-mix the aggregates with app. half the water[2]
- Add **AALBORG WHITE®** (and fillers, if any)
- Add remaining water (consistency like moist soil)
- Add 2/3 of the super plasticizer
- Add air entrainment agent
- Add remaining super plasticizer

[1] The long mixing sequence takes three minutes as described here, but may be less for efficient mixers. However increased mixing time relative to normal should be expected in order to obtain robust uniform mixes from batch to batch.
[2] For very efficient mixers, premixing may not be necessary

3. Examples of AALBORG WHITE® based SCC mixes

The SCC mixes in Table 2 have displayed acceptable properties in laboratory testing. On industrial mixers, they can not be expected to display the exact same behaviour without modification, but minor modifications in especially water content should make it possible to reach very similar behaviour.
Particle size distributions for individual aggregates and final mix combinations are shown in Table 3 and Figure 3

Table 2: Examples of SCC mix designs based on AALBORG WHITE® [kg/m³].

Material	Mix 1	Mix 2	Mix 3
AALBORG WHITE®	350	390	410
Glacial sand	648	457	427
Quartz sand 1		229	
Quartz sand 2			290
Sea dredged rounded gravel 4-8	270		
Sea dredged rounded gravel 8-16	882	1072	
Crushed granite 4-8			198
Crushed granite 8-16			793
Water	138	141	167
Air entrainment agent	0.4	0.4	0.5
Super plasticizer	3.0	3.5	3.6
Flow spread [mm]	600	630	600
T_{30} [S]	2.0	1.9	1.9
T_{50} [S]	3.6	5.6	4.8
T_{max} [S]	21.9	24.8	19.3
Air content [%]	6.4	5.4	4.8

Dosages depend on additive type

Flow spread and flow time depends on used method. These values were obtained with a 300 mm inverted cone.

Table 3: Gradation of aggregates used in the examples and total grading curves.

Sieve [mm]	Glacial sand	Quartz sand 1	Quartz sand 2	Sea gravel 4-8 mm	Sea gravel 8-16 mm	Granite 4-8 mm	Granite 8-16 mm	Mix 1	Mix 2	Mix 3
32	100	100	100	100	100	100	100	100	100	100
16	100	100	100	100	100	100	100	100	100	100
8	100	100	100	97	10	100	3	56	45	54
4	100	100	100	17	4	91	2	41	41	43
2	98	55	81	6	2	3	0	37	34	39
1	88	32	71	4	2	2	0	33	28	34
0.5	55	8	18	3	1	0	0	21	16	17
0.25	15	1	0	1	1	0	0	6	5	4
0.125	4	0	0	0	0	0	0	1	1	1
0.075	1	0	0	0	0	0	0	0	0	0

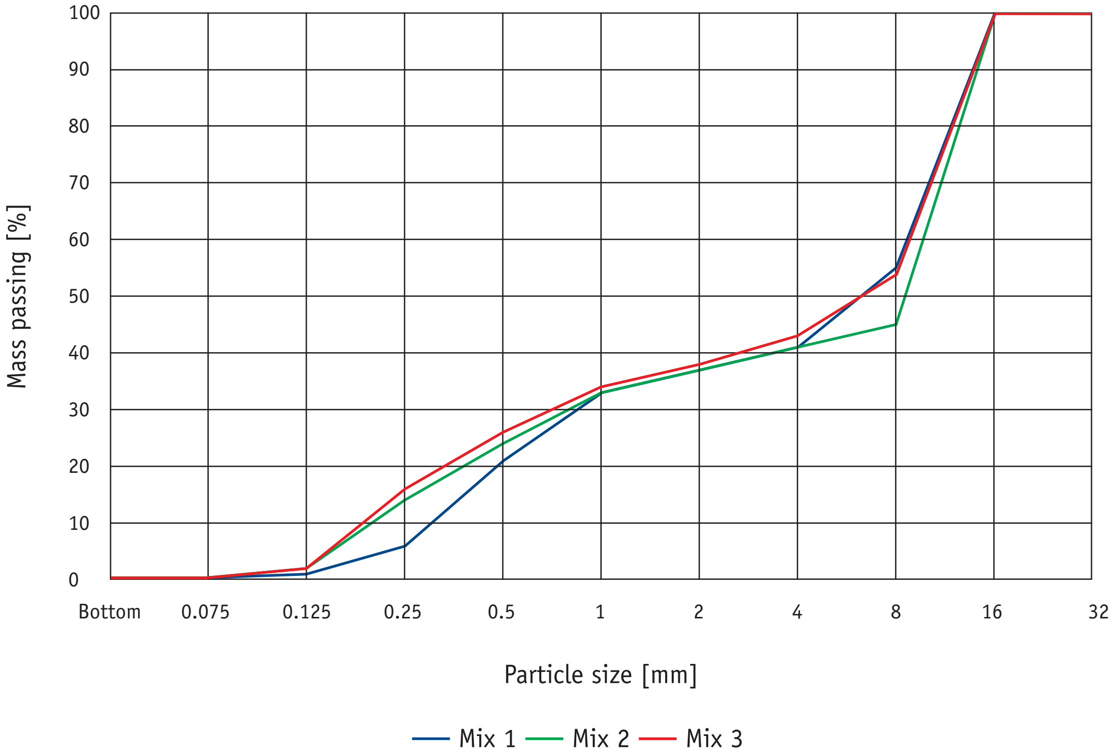


Figure 3: Grading curves for the three examples.

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