4. CONCLUSIONS

The potential of soluble alkalis to enhance early strength and diminish late strength of Portland cement has been demonstrated in ISO-mortar as well as in two concrete compositions. The strength changes expressed on a relative basis were of the same order of magnitude in these systems. The tendency of increased alkali contents to promote higher water demands can add an extra negative effect to the strengths at all ages if the effect of alkalis is evaluated on a constant slump basis.

Preliminary tests with blends of Portland cement with a granulated blast furnace slag, a fly ash and a microsilica have indicated that the influence on strength from such mineral admixtures is only modestly - if at all - dependent on the content of soluble alkalis on the cement.

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EXPERIENCES FROM THE USE OF F-CEMENT - A BINDER BASED ON ALKALI-ACTIVATED BLASTFURNACE SLAG

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1. ABSTRACTS

To meet the demands of the modern prefab. industry for a concrete giving high early and ultimate strengths a new binder, called F-cement, has been developed in Finland.
The cement consists mainly of a finely ground well granulated BFS used together with an admixture consisting of alkaline activators and a superplasticizer. The technical properties of the cement are very good and it can be used as an LH and SR cement.
The investment and production costs are low because no burning is needed.
The cement has been tested in full scale in ab. 40 prefab. factories in Finland and abroad. The first building made in F-concrete was erected last year in Rauma, Finland.

Keywords: Alkaliactivation, BFS, F-cement.

2. THE COMPOSITION OF F-CEMENT

The F-cement consists normally of 2 componets, namely a base-material and an admixture but can also be produced as a dry 1 component binder. As base-material is normally used a well granulated blastfurnace slag sometimes with addition of other metallurgical slags, natural or technical pozzolanes, PC or clinker etc. Fly ash addition up to 50% of the base-material weight has been used without detrimental effect on the strength. There is no special demands on the chemical composition on the BFS and slags even with low Al_2O_3-content have given base-materials with excellent strength properties.
The base-materials are activated by the F-admixture consisting of an alkaline solution of different salts and an effective usually lignosulphonate-based superplasticizer. The admixture is normally used as a solution with 25% dry material. The ratio of the admixture, used,calculated as dry, to the base-material is normally 4-7%.

3. PROPERTIES OF THE F-CEMENT AND -CONCRETE

Although the F-cement is based on by-products and wastes it is not to be looked at as a simple and cheap substitut for PC,but offers in many respects superior engineering properties compared to PC. The CaO/SiO_2 ratio of this binder is much lower than in PC and no free lime has been found in the hydration products. F-cement contains no C_3A and has thus excellent sulphate resistance properties. By the same cement content/m^3 the F-cement usually gives 20-30% higher compressive strength than OPC. The compressive strength being the same, the F-cement shows about 20% higher flexural strength.
Although the air content is low, usually only 1/2 - 1% the F-concrete is frost resistant. The shrinkage of the F-concrete is somewhat less than for corresponding PC-concrete, the creep about the same.

The water demand of the F-cement is ab. 30% lower compared to corresponding PC-concrete. Thanks to the low water demand and low air content the porosity of the F-concrete is compared to corresponding PC-concrete 40-80 $1/m^3$ lower. This gives a dense concrete with high durability.
The F-concrete is flowing even at low w/c-ratios, is easy to vibrate, is strongly cohesive, and shows thixotropic behaviour in dry mixes.
The heat of hydration is about 1/2 of that of PC. To get high early strengths a moderate heat curing is therefore needed.
The open time of F-concrete is usually longer than for PC-concrete. The properties of the fresh and the hardened concrete can be varied within broad limits by changing the composition and amount of the admixture.
Due to the low heat of hydration of the F-cement the strength increase is slow at low temperatures. A thermal curing of F-concrete is therefore recommended.
The F-admixture is strongly alkaline and special precautions are needed by the handling. Because of the large amount of admixture used 15-30% of the weight of the F-base-material, bigger admixture containters than usual are needed at the prefab. factories.
The biggest disadvantage of the F-cement is that it is not a PC. Special permissions or type approvals are therefore today needed for the use of this new cement.

4. EXPERIENCES FROM THE USE OF F-CEMENT IN CONCRETE

The F-cement has today been used in full scale tests and production under a period of only 2-3 years, but the experiences are so far good.
The biggest differences compared to PC-concrete appears in the rheological behaviour of the fresh concrete, and this has to be taken into due consideration both at the mixing and the casting for a successful use of this new binder.
As earlier mentioned the F-cement gives already with low w/c ratios a flowing concrete, and even very dry F-concrete mixes are fairly easy to compact. The high early strengths reached already by moderate thermal curing (40-50°C) and the good ultimate strengths makes this cement very suitable to meet the demands of the prefab. industry for a more effective use of the moulds.
During the elapsed introduction period the F-cement has been tested in a variety of elements made of fresh concrete of different workability. Although the F-cement has been developed especially for production of flowing concrete, its use in dry mixes has been very successful.
During the introduction period the F-cement has been used both for element production and for concrete casted in situ in a normal way and by pumping. Especially in dry mixes, in flowing concrete and in concrete when cement rich mixes has been used the use of F-cement has proven advantageous.

4.1. Storage of the components of F-cement.

The base-materials are stored and handled in the same way as normal cement. Storage of the F-admixture of low temperatures

should be avoided because the risk of flocculation and crystalisation due to low solubility of some components in the admixture.

4.2. Design and mixing of F-concrete.

F-cement is used in concrete in the same manners as normal PC. The admixture is preferable added at the mixer. Design of a F-concrete mix is done in the same way as for a PC-mix, taking into account the ab. 30% lower water demand and the low air content.
The dosage of the admixture is preferable done by an automatical pump. For the mixing the use of pan mixer is recommended. The workability of the mix is somewhat difficult to judge by eye due to the sticky character of the fresh concrete. Even the resistance meter doesn't give much help. By measuring the slump, the time has to be fixed.
Even by big differences in the workability there are only small differences in the real w/c-ratios and thus in the strength properties. Although big dosages of OPC in F-concrete have a stiffening effect on the consistency F-concrete can be mixed in the same mixer as PC-concrete without cleaning. Due to the stickyness of the F-concrete somewhat longer mixing times and smaller baches than with PC-concrete are recommended.

4.3. Casting and compaction of F-concrete.

Although the F-concrete normally is flowing, the deformation proceeds slowly but for a long time. Quick moulding of the F-concrete is not very successful and the vibration parameters are to be adjusted to get optimum effect. Usually the vibration effect can be markedly reduced. Even very dry mixes can fairly easely be compacted by vibration.
The F-concrete can be pumped by normal pumping equipment, but the pumping resistance is higher than for normal concrete. Concrete with 32 mm max aggregate size has been pumped without difficulty. The tendency for separation of F-concrete is very low even in flowing mixes.

4.4. Curing

In order to get high early strengths the F-concrete has to be thermally cured. By using the same amount of cement and adjusting the w/c-ratio to get the same workability the demoulding strength can normally be increased 2.5 to 3 times by using of F-cement instead of OPC. By production of wall elements in a battery-mould the demoulding strength increased from 20 to 55 MN/m^2 by the use of F-cement. In an IR-curing-kiln the demoulding strength of a facade element made of the F-cement increased from 10 MN/m^2 to over 30 MN/m^2 after 4 hours curing.

4.5. Full scale tests.

F-concrete has been successfully tested in full scale in about 40 factories in Finland and abroad. The cement is type-approved in Finland and 2 prefab. factories have got type-approval for elements made of F-concrete. A factory in Sweden will start a

production of piles made of F-concrete after the summer vacation.
Railway-sleepers and hollow-core slabs have been produced with concrete with w/c as low as 0.20 and piles have been casted without vibration with concrete with a w/c 0.27-0.28.
The first building made of F-concrete was erected last autumn in Rauma in Finland. It was a bulk storage building where concrete with a good sulphate resistance was asked for. In the building prefab. wall element, pillars and beams made of F-concrete were used. The floor and the deck was casted in situ. The experiences from the prefabrication was very good. Although the thermal curing was very moderate, the elements could be demoulded by a maturity of ab. 500°C x h and brought directly to the building site and erected. The floor was casted by pumping without vibration, and 2 men were able to cast ab. 500 m^2 floor in one shift.
The experiences from the practical applications of F-cement and concrete are until now very promising.

PRELIMINARY INVESTIGATION OF ALKALI-SILICA REACTIVITY OF DENSITY SEPARATED COARSE AGGREGATE

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1. ABSTRACT

Danish flint is a mixture of two basically different rock types:

- calcedony containing flint
- opal containing flint.

Both types can be calcareous.

The opaline flint types are in general lighter than the calcedony carrying flint types, and can to some extent be separated by heavy media separation. Opaline flint occurs as individual particles, but also as crusts on calcedonic flint. The opaline flint is strongly alkali-silica reactive, besides giving a risk of creating frost damage.

To test what advantages could be gained by heavy media separation, samples of stones were separated into narrow density-fractions as follows:

> 2500 kg/m^3, 2500-2400, 2400-2300, 2300-2200, > 2200 kg/m^3.

In addition the heavy fractions were handpicked into:

"granitic" rocks
limestone
calcedonic flint (pure)
calcedonic flint with opaline crust.

Both the heavy media separated and the handpicked stones were divided into 8/16 and 16/32 mm fractions.

The reactivity of the individual stone fractions were tested by casting concrete test cylinders with a non reactive sand, and storing them in a saturated NaCl-solution at 50°C. At regular intervals the samples were inspected for any sign of damage.

The lighter, coarse aggregate fractions, containing mainly opaline flint, developed pop-outs and produced large amounts of gel, but developed no fractures.

The heavier fractions, above 2400 kg/m^3 contained calcedonic flint with opaline crusts. These developed pop-outs, some gel and produced cracks extensively. Samples with pure calcedonic flint did not show any sign of damage in 8 weeks.

Two different size fractions were used, 8/16 mm and 16/32 mm. The results showed more severe damage with the small stones. This might be due to the expansion centers becoming increasingly better distributed the smaller the grain size, and the situation approaches the situation where the reactions are caused by reactions in the sand fraction.

The experiments will be described, and the results will be illustrated.