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SELF COMPACTING CONCRETE AN INOVATIVE CONCRETE

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ABSTRACT: Self-Compacting concrete (SCC) it is considered to be one of the most successful innovation in industry of construction. The development of a more fluid concrete brought many advantages such as improvements in productivity, energy consumption, working environment, quality. In a short time self-compacting concrete has developed in different areas of construction industry; so it can be used for in situ application as well as for precast production. Self-compacting concrete is not only an alternative material to normal vibrated concrete it also opens the possibility for radical changes in whole construction process. This paper shows the necessity of this kind of concrete and presents the key properties that makes fresh concrete self-compacting, and presents the tests methods such as: Slump flow, J-ring, L-Box and V-funnel which are evaluated theoretically.
KEYWORDS: concrete, compaction, quality, fly ash, flowability, fluidity

INTRODUCTION

Originally developed in Japan in the early '90s, it has rapidly been adopted by the worldwide construction industry. If we want to define this material its name offers us a full definition, Self-Compacting concrete (SCC) does not require any compaction. This property of self-compatibility refers to the behaviour of a concrete mix in its fresh state which has the ability to flow under its own weight, fill the required space or formwork completely and produce a dense and adequately homogeneous material without need for compaction [1-3]. It is important to make the difference between a fluid concrete and a self-compacting concrete, it isn't enough to flow, self-compacting concrete mixes besides a very high workability, it completely resist segregation and it maintains its stable composition through transport and placing.

THE NEED OF SELF-COMPACTING

A concrete which is easy to handle and place, it will be always a concrete preferred by the industry of construction. A flowable concrete can be achieved by adding more water to the mix or by increasing the amount of cement paste. Increasing the level of water content in the mix should be avoided because it leads to severe segregation and greatly reduces the strength of the hardened characteristics of the obtained concrete.

The second option to increase flowability it was to increase cement paste content but this led to economic problems, increasing the cost of such a concrete.

Figure 1. Poorly compacted concrete

Fresh concrete of a moderate-low slump therefore prevailed in practical concrete construction [4]. In order to achieve a good strength of the material the solution was to achieve a full compaction. The most common method for compaction is the internal vibrators (poker), external vibrators and vibrating tables. The scope of vibrating the concrete is to "liquefy" the fresh mix and temporarily increase its consistence so that the air trapped in the mix is able to rise to the surface and escape from the mix [5]. Although there many guidelines about vibration and compaction, a significant proportion of concrete mixes which can be fully compacted was never found. In figure 1 it can be seen the inadequate compaction, but in many other cases is not apparent and remaines hidden within the *mass of concrete and reinforcement and this is considered one of the principal cause of poor performance of both plain and especially reinforced concrete.*

a) b)

Figure 2. a) Poor compaction of a reinforced concrete column
b) The huge number of workers involved in the compaction process

Compaction of concrete in which handheld poker vibrators are used, is very physically demanding work and often carried out in very difficult environmental conditions, usually made by untrained labourers.

Compaction of normal vibrating concrete during casting floors and slabs is inefficient because of the large number of workers like fig.2 b).

Compaction of concrete in general is considered to be beneficial in improving the perceived "homogeneity during placing and thus the properties of the hardened concrete [5]. This view was taken for granted for a long time until the SCC introduction on the market of Iceland, when Wallrvik and Nielsson [6] made an investigation on specimens with 'good' compaction by a poker vibrator. The specimens were cut into numerous slices after hardening and distribution of constituents was established. The results of a systematic study of the homogeneity following a "good" compaction by poker vibrators indicated that the uniformity of the hardened concrete actually decreased [5]. This was a small scale project focussed on local concrete mixes, [5] and the results do not mean that compaction is not needed [5].

Poor compaction like the one presented in fig.1 and fig.2 that need a compaction with poker vibrators decreases quality, causes delays and increases the actual concrete construction cost. All this can be a good reason in using SCC.

MATERIALS AND METHODS OF TESTING SCC

Self-compacting concrete (SCC) doesn't have special components, in its mixes can be used materials according to standards and specifications for use in concrete. However SCC mixes request a uniformity and consistency of supply throughout the production of the concrete.

***Cement -** SCC requires high powder content and a low water/powder ratio. Early studies were based on the use of a low heat, high belite content Portland cement. [7] All kind of cements can be used if it respects the standards and the specification from SR EN 197-1.[8]*

***Addition -** The addition it is used for the stability of the mix and it has a significally importance in segregation. The addition includes two types (EN-206-10) [9] inert or nearly inert additions: limestone, fly ash (type I) and puzzolanic or latent hydraulic additions: silica fume, ground granulated blast furnace slag (type II). Quantities are usually 5-50% and the addition controls the strength, reduces the heat of hydration and therefore reduces the risk of cracking from thermal strains, improves stability and rheological behaviour.*

***Coarse Aggregates -** In order to achieve high flowability for SCC properties, the aggregates should preferably have a maximum size 16mm or 20mm depending on local availability and practice [10]. It is preferably to use rounded uncrushed aggregates, if this is not possible in some areas crushed rock are commonly used. An analysis of 63 case studies published between 1993 and 2003 show that crushed rock was used in over three-quarters of these studies [10]. Lightweight aggregate has also been successfully used to produce SCC with a density of 1900kg/m^3 for large scale production of precast building panels. [11, 12] The conclusion is that SCC mixes can be done with local coarse aggregate without major influence for the mix design.*

***Fine aggregate -** Sand improves stability of SCC mixes; therefore it may be beneficial to blend manufactured sand with natural sand.*

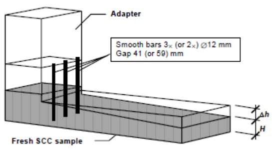
***Admixtures -** The most used admixtures are the water reducer admixtures SR- EN 934-2 [13], also in the SCC's mixes are used viscosity admixture which are beneficial for adjusting the viscosity and improving the stability of SCC.*

TEST METHODS FOR MEASURING SCC CHARACTERISTICS

For a successfully mix design of SCC there are few steps [13] which must be done in order to achieve a properly proportioning mixture. First, must be determined slump flow performance requirements, then select coarse aggregate and proportion [14], estimate the required cementious *content and water; calculate paste and mortar volume, select admixture; batch trial mixture; test. There are three key properties of fresh SCC: filling ability, passing ability, segregation resistance.*

All three keys must be reached for fresh concrete to be self-compacting to remain so until placing. Table 1 presents test methods for measuring SCC characteristics.

Table 1. Test methods for measuring SCC characteristics

<table>
<tr><th rowspan="2">Test methods</th><th rowspan="2">Description</th><th colspan="6">Test results (Classes of SCC)[16]</th></tr>
<tr><th colspan="6">Slump flow spread (mm)</th></tr>
<tr><td rowspan="2">Slump flow
(filling ability)
</td><td rowspan="2">The test determines the difference between the values of maximum diameter (d_m) and perpendicular one (d_p). If the difference exceeds 50 mm the result of the test is rejected as unreliable.
- Finds the average of d_r and d_m and record it at the resulting slump-flow spread SF (mm) to the nearest 10 mm.
- Records the flow-time t_{50} to the nearest 0.5s.
- Determines the visual stability index (VSI) through rating the apparent stability of the slump flow (Daczko and kurtz 2001) [17]</td><td colspan="2">SF1</td><td colspan="2">SF2</td><td colspan="2">SF3</td></tr>
<tr><td colspan="2">550-650</td><td colspan="2">660-750</td><td colspan="2">760-850</td></tr>
<tr><td rowspan="2">L-box (passing ability)
</td><td rowspan="2">The method measures the passing ability of SCC evaluating the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. The basic result of the L-box test is the passing ratio PR = H_2/H_1, calculated the nearest 0.05.</td><td colspan="3">PR1</td><td colspan="3">PR2</td></tr>
<tr><td colspan="3">PR≥0.80 with 2 reinforcement bars</td><td colspan="3">PR≥0.80 with 3 reinforcement bars</td></tr>
<tr><td rowspan="2">Sieve segregation
</td><td rowspan="2">The method measures the resistance of SCC to segregation [18] by measuring the portion of the fresh SCC sample passing through a 5 mm sieve.
The degree of static segregation is assessed by calculation of the Segregation index (SI) as the percentage proportion of the mass of concrete, which passed the sieve from the total initial mass poured into the sieve.</td><td colspan="3">SI1</td><td colspan="3">SI2</td></tr>
<tr><td colspan="3">SI1≤20</td><td colspan="3">SI2≤15</td></tr>
</table>

Of course there are many other ways to define the rheological properties of a self compacting concrete, like the Orimet, the J-ring, V-funnel and others.

APPLICATIONS IN THE PRECAST CONCRETE INDUSTRY

It is known that self-compacting concrete mixes are sensitive to variations in composition and environmental influences. Because in the precast industry the materials, transportation of the concrete can be easly controlled, SCC is one of the best choice for this area of construction industry. The advantages for using SCC in precast concrete plants are: the substantial reduction of the noise level, the absence of vibration, the energy saving, the omission of the expensive mechanical vibrators, the possibility to produce elements with high architectural quality.

Figure 3. Architectural element SCC

As we can see in Figure 3, an example of an architectural balcony element of SCC, the element has beautiful shape with very sharp profiles and a homogeneous white color.

Figure 4. Foundation piles SCC

Figure 4 shows a set of foundation piles. The production of such type of piles in the firm was 70 000 piles a year. Recent studies showed that in this kind of elements the time was reduced from 7.5 minutes to 1.5 minute, in this case we must take also into account the advantages with regard to the reduction of noise, energy consumption.

Figure 5. Concrete arches made of SCC

Figure 5 shows a number of concrete arches made of SCC. Producing such an element with conventional concrete it's almost impossible, an alternative can be by making it in parts but is by far time consuming and therefore expensive. Meanwhile many precast concrete companies changed their production because they realized that with SCC perfect elements could be made.

CONCLUSIONS

1. *In spite of its short history, self compacting concrete has confirmed itself as a innovative concrete which revolutionized the concrete technology.*
2. *For the application of SCC in situ, it is necessary that the SCC's mixes to be designed for any particular case.*
3. *In spite of the slightly higher material price, it can be shown by cost analysis, that SCC can be more economically produced than conventional concretes,. Cost comparisons should always be made on the basis of integral costs.*
4. *The most important task for research is to develop SCC's with decreased sensitivity to variations in constituents materials and environmental influences.*

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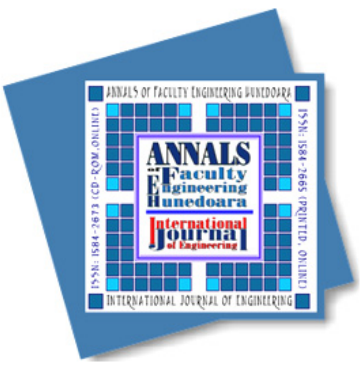

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