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SELF COMPACTING CONCRETE IN BUILDING INDUSTRY

BY

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Abstract. Self compacting concrete (SCC) was presented by Japanese prof. Okamura in 1986 and is characterized worldwide as one of the most significant development steps in concrete materials technology. This new mixture was created to improve the quality and durability of concrete structures, achieving full compaction under its own weight without vibration. Its high fluidity provides new possibility to create complicate structural and architectural shapes. Since its discovery, SCC was seen as special material, only applicable for one of the occasions, which has yet to be fully accepted. Its sensibility with respect to variations of quality and of moisture of constituent materials demands more vigilance than for conventional concrete. The use of SCC in precast concrete plants has grown considerable, some of them are using it solely, but the introduction in-situ application was slower. Only a limited number of published papers described SCC on-site applications, the largest part of research to date has focused on mechanical and rheological performance properties.

Keywords: self compacting concrete; production; benefits; applications.

1. Introduction

The concrete compaction is decisive in achieving a durable material and requires skilled workers to carry out the process. In the early 1980's, due to the lack of qualified labor in Japan, were been attested a substantial proportion of "poor compacted" concrete placed in-situ applications, which affected the quality of the construction process. In order to solve that problem, it was

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developed a durable concrete without the need for vibrating compaction, the result of which was SCC.

Self-compacting concrete, or self-consolidating concrete that is the most used term in North America, was presented by the Japanese prof. Okamura in 1986 and is considered as one of the most progressive steps in concrete materials technology during the last decades. This new type of concrete, with hight viscosity is able to flow under its our weight, filling completely the formwork, even in the presence of congestioned reinforcement with no additional mechanical compaction. The elimination of vibration leads to an improved concrete quality, decreased skilled labor and shortens the time needed for construction. On the other hand, vibrating the concrete creates noise that has noxious physical impact on workers and affects the surrounding neighborhood.

2. SCC production

SCC components are similar to vibrated concrete: cement, mineral admixtures, aggregates, mineral and chemical admixtures and water. Its performance in fresh state is based on new types of superplasticisers (PCE) associated with high powder contents (industrial by-products) or special fine-grained sand. Alternatively, a viscosity-modifying agent (VMA) can be introduced to the concrete mixture composition when no or limited filler amount is used.

SCC is normally less tolerant to quality deviations in constituent materials and their moisture fluctuation. This circumstance affects the ready-mix production in concrete plants; also the transportation, as well as the casting process involves a more rigorous monitoring than conventional concrete. To attain SCC with specified properties in fresh and hardened state, not only material composition has to be optimized, but the entire process demands adequate management, skills and training.

SCC may be classified in three basic mixture proportioning types:

a) *the powder type SCC* is characterized by large amounts of powder which is usually between 550 and 650 kg/m^3. The paste acts as a ‘lubricating’ coat that allows deformation, whilst sufficiently supporting the aggregates in a state of suspension. This ensures the plastic viscosity and consequently the segregation resistance increases. The yield point is established by the adjunction of superplasticizer;

b) *viscosity type SCC* contents lower quantity of powder, 350 to 450 kg/m^3, a high water/cement ratio and high water/powder ratio. VMAs operate by modifying the concrete’s structure at a microscopic level, enhancing viscosity, yet inhibiting flow, with the joined effect of improving stability and diminishing potential for segregation. The yield point is generally regulated by the addition of superplasticizer;

c) *combination type of SCC* combines elements from both powder SCC's and VMA SCC's. The powder quantity varies between 450 to 550 kg/m^3, supplementary, the rheology is also regulated by a VMA as well as a proper dosage of the superplasticizer.

3. SCC Transporting, Placing & Finishing

The equipment, constituent materials as well as the process for production of ready-mix SCC in concrete plants should be meticulously controlled. However, if any conditions are changed, there may be significant differences between performance of SCC in fresh and hardened state at the same recipe.

The type of mixer, mixing time and the ways to loading affect the SCC properties. The constituent materials should be mixed in such a way that the mixture ends up being uniform. The necessary mixing period is influenced primarily by the mixer variety and the proportions of the constituents. The free-fall mixers require additional mixing time as they are less efficient than forced action mixers.

The fluid nature of SCC involves a volume diminution in delivery load to prevent the loss of material during transportation from ready mix concrete plants to construction sites; 5m^3 carried in a 6m^3 capacity truck. The transportation of SCC has to be properly executed in order to maintain the fresh properties on the site. The time factor is of large importance. Prolonged waiting interval between the deliveries may result in thixotropic thickening behavior of the already cast concrete. The 'layer tendency' amount separate deliveries may produce an inhomogeneous concrete microstructure.

The casting process of SCC differs from traditional casting of normal concrete, where the vibration work is an essential part. SCC casting is more rapid, less noisy and less complicated. However, there are also difficulties connected to the fresh properties of SCC, which must be considered. The recommended method of placement for SCC is removing the issue of 'freefall', which causes air entrapment and segregation.

SCC exerce an increased lateral pressure of the formwork due to its highly fluidity. Field investigations showed that pumping of concrete from the bottom decreased formwork pressure. The reduction may be related to a potential decrease of the hydraulic head due to the friction between the rising concrete during placing and the surface of the formwork. The ability of SCC to recover its original viscosity and cohesiveness soon after placement contributes to decreasing lateral pressure. The factors influencing the formwork lateral pressure are height and rate of placement, placing method, rheological properties of fresh concrete, shape and size of aggregate, setting time, type and amount of admixtures as well as formwork design.

4. The Benefits of and Barriers Against Using SCC

The greatest advantage of SCC is the elimination of traditionally needed compaction work as the fresh mixture flows under its own weight and fill the formwork even in congested reinforcement areas (Fig. 1). This opportunity means that several potential benefits may be exploited to cover various domains: enhanced structural design, increased production efficiency and ameliorated building function.

Fig. 1 – Flowability of SCC (Henderson, 2000).

The homogeneity of SCC is higher than of the conventional concrete, which leads to less variation in mixture production and less deviation in strength. The other advantage using SCC is increasing surface quality of concrete that doesn’t require refinishing before painting of the walls.

Last but not least, cost will decrease as manpower reduces during placement of fresh concrete. SCC means no vibration, less restriction to design resistance to segregation, less restriction to particle.

Any economic advantages with SCC are primordially linked to modifications in construction processes: increased workability, reduced number of skilled workers achieved through the removal of the compaction process. Consequently, it presents an opportunity to make savings in plant and equipment.

The main advantages for contractors in use of SCC are: rapid concrete pumping, uniform and compact surface with less surface voids and need for rubbing and patching, improved aesthetics of flatwork for less effort, and reduced labor and construction time.

The benefits for ready-mix producers are**:** better perception from customers by offering a technically advanced, higher value concrete mixture, faster truck turnaround, more efficient use of mixing equipment and delivery, all of these easily expands variety of products offered without adding more equipment, improved aesthetics of final product.

Compaction of conventional concrete produces noise of around 93 dB, which affects working environment by causing deafness, stress and fatigue. The use of SCC is safer and reduces the noise levels in built-up areas well below 80 dB, hence no ear protection is needed and communication on site is easier. Vibration above 0.25 m/s^2 causes pain and stiffness in limbs, back and neck, vibration levels from 0.75 to 4 m/s^2 affects the blood circulation of the vibrator operator.

The SCC composition includes a large amount of industrial products: limestone filler, fly ash, silica fume, ground-granulated blast-furnace slag used as cementitious materials. The reduction of cement quantity involves a lower emission of CO_2 during its production.

5. Barriers Against Using SCC

The differences between conventional and SCC mix design create a number of potential problems when SCC is used in place of conventional concrete. Producers of SCC have to prove increased vigilance in the supervision of processing and material storage. The sensitivity of SCC to variations in constituent materials requires implementation of additional measures to ensure the desired quality. Additional importance in storage of constituent materials should be paid to prevent cross-contamination between different types and sizes of aggregates. In order to defend against the excess moisture during rainwater, it is recommended to allow free drainage of aggregates.

Also, the producers have to create their own optimal recipe, as is extremely rare for a single mix design to be used in a multitude of locations. Determination of the suitability of SCC for each application is essential to the final quality of a concrete element. The tests needed to check it acceptance on the job site are more complex and numerous.

The presumptive disadvantages of SCC consist in high form pressure due to its fluidity and increased sensitivity to plastic shrinkage and early cracking.

The placing of SCC on site should be realized by trained personnel in the specific requirements. During this process, the concrete should be regularly verified to ensure that coarse aggregate is remaining suspended in paste and that there is no indication of segregation. An increased vertical casting rate may produce a large volume of entrapped air due to the insufficient time to rise to the surface and escape.

Conventional method of placing concrete by free fall may lead to segregation, which is why the height should be limited. Japan Society of Civil

Engineers recommends maximum free drop height be around 5 m or less and maximum lateral flow distance between 8 and l5 m.

Pumping SCC generally leads to reduction of the slump flow, that is why the type, the number, the diameter and the length of pumps must be adopted with thorough consideration to test results and field experience.

Initial curing should start after surface finishing in order to reduce the potential of crusting and shrinkage cracks due to early age moisture evaporation.

6. Applications of SCC

Previously, SCC was seen as specialist material, used only for a limited number of constructions. However this generalized aspect is changing, making SCC the most widely used concrete.

The largest part of SCC research has analyzed mechanical and rheological properties, and less on-site applications. Through literature it has been shown that there exist a lack in understanding the SCC introduction to projects, the roles of project teams and team members, proper approach to problems caused by differences between SCC and conventional concrete.

6.1. Applications of SCC in the Precast Concrete Industry

For the precast concrete industry the introduction of SCC to current production doesn’t mean an important effort, since the processes at the plant can be very well controlled. The advantages of using SCC in precast concrete plants are very considerable:

a) the essential reduction of the noise level;
b) the elimination of vibration;
c) the reduction of dust in the air caused by vibration;
d) low energy consumption;
e) the exclusion of the costly mechanical vibrators;
f) the minimisation of wear to the formwork;
g) the eclusion for the installation of vibration isolators;
h) increased environmental safety;
i) the oppotunity to produce elements with high architectural quality (Fig. 2).

For the successful production of SCC it is important that the basic constituents, like sand, gravel, fillers and superplasticizers, have a constant quality. The proper strength for demoulding SCC is attained faster than for traditionally concrete, in addition, the used formwork content elementary connections that contribute to a reduction of time for demoulding and re-installing the formwork by 50%.


Fig. 2 – Precast elements of SCC (Goodier, 2003).

6.2. Applications of SCC in situ concrete industry

The launching of SCC for in-situ applications required a long time than in the precast concrete industry. There are a number of reasons for this:

i) the consequences of a failure are more severe than in the precast concrete industry;

ii) there is no agreement on the way in which the properties of fresh SCC at the building site have to be controlled;

iii) difficulty to obtain robust and reliable SCC with lower concrete strength, usually used in site applications.

Slabs are casting in a distinct way than conventional concrete mixtures. It is recommended to discharge SCC at one point and let it flow into place before moving the point of placement (Fig. 3). Simultaneously, it's necessary to respect he maximum admissible horizontal spread distance.

For modules, columns and thin walls SCC should be placed into the central part and then allowed to distribuite over the edge and into the wall. A different method to supply is to pump them from the bottom of the formwork, for complex shapes it is desirable to pump from several locations.

The use of SCC in situ applications means optimised casting process with less need of skilled workers, speedy production cycles and reduced production costs.

Fig. 3 – Placing slab of SCC (Gaimster & Foord, 2008).

7. Conclusions

Self compacting concrete is an innovative building material, a durable concrete that fills the formwork without the need for vibrating compaction. It is more homogeneous and has less variation in production of concrete and less deviation in strength. This new type of concrete can be characterized by:

a) more sensitive to variations in the fresh state than conventional concrete, and requires more vigilance in production, transportation and casting process;

b) decreases the final cost of construction, due to the elimination of vibration, reduced manpower and shortened time;

c) the fluidity of SCC leads to a higher form pressure and increases the sensitivity to plastic shrinkage and early cracking;

d) removing vibrations means less restriction to design, and improved resistance to segregation.

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UTILIZAREA BETONULUI AUTOCOMPACTANT ÎN INDUSTRIA CONSTRUCȚIILOR

(Rezumat)

Beton autocompactant (BAC), caracterizat la nivel mondial drept una din cele mai importante descoperiri din industria materialelor de construcții, a fost prezentat pentru prima dată publicului larg în 1986, de către profesorul japonez Okamura. Acest material are capacitatea de a se compacta sub influența greutății proprii, fără necesitatea de a fi vibrat, astfel asigurând o creştere a calității şi durabilității structurilor din beton. Fluiditatea amestecului proaspăt crează noi oportunități la realizarea elementelor structurale şi arhitecturale cu o geometrie complexă. Inițial, BAC a fost considerat un material special, aplicabil doar în unele circumstanțe, accesibilitatea căruia urmează a fi pe deplin valorificată. Sensibilitatea acestuia față de variațiile de calitate şi umiditate a constituienților impune o monitorizare mai riguroasă în timpul producerii, transportării şi manipulării. Spre deosebire de industria prefabricatelor, unde folosirea BAC a crescut considerabil, unele fabrici utilizând în exclusivitate noul material, procesul de introducere pe şantierele de construcții decurge mai lent. Majoritatea lucrările ştiințifice

făcute publice în literatura de specialitate, au fost consacrate studiului caracteristicilor fizico-mecanie şi metodelor de producere, drept urmare, particularitățile aplicării practice în industria construcției au fost examinate mai puțin.