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TECHNICAL-ECONOMIC INDICATORS OF SELF-COMPACTING CONCRETE STRUCTURES

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Abstract: *Self compacting concrete (SCC) was presented by Japanese prof. Okamura in 1986. It was developed to increase the quality and durability of concrete structures. This new mixture achieves an adequate compaction under its own weight due to its high fluidity that provides opportunities to create complicate structural and architectural shapes. The higher powder content is often supplemented by waste materials and industrial by-products that make the concrete friendly with the environment. The material costs of SCC are higher than costs of vibrated concrete, but thanks to its workability, it can be placed at a faster rate with no mechanical vibration in a shorter construction period, which leading to cost savings in placement.*

Key words: *self compacting concrete, labor, construction time, cost.*

1. Introduction

Concrete has become one of the most popular construction materials in worldwide due to the possibility of use the locals raw materials. This fact led to many inventions in the field of concrete and determined many researches in order to enhance its quality, reducing the cost of implementation. Another test facing the engineering community is to perform projects using the concept of sustainable development. [2]

SCC is one of the most significant discoveries of contemporary concrete. It was developed to increase the quality and durability of concrete's structures with less labor that reduce the amount of skilled workers. This innovative mixture is characterized by:

- flowability - fills thoroughly the formwork, - passing ability -flows thought rebar, around obstructions
- stability - without segregation.

SCC achieves an adequate compaction under its own weight, without any vibration. The higher powder content of SCC is often completed by supplementary cementitious materials, most commonly used are waste materials and industrial by-products that makes the concrete friendly with the environment specifically when it is used as a exposed construction material.

The advantages of SCC in fresh and hardened states lead to an economical efficiency: reduce of labor, increase of safety, improving product finish, decrease form maintenance, the equipments costs,

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the electrical consumptions and construction time [3].

2. Composition of SCC

The constituent materials used for the production of SCC are the same as those for conventionally vibrated normal concrete, except that SCC involves a low water/powder ratio, a limited quantity of coarse aggregate and an increased volume of paste. The higher powder content is often supplemented by mineral admixtures – waste materials and industrial by-products

To achieve an SCC of high fluidity and avoid the segregation it is normal to use a high dose of the polycarboxylate admixture of new generation or viscosity-modifying agent (VMA) into the concrete mix. The use of these admixtures increases significantly its cost compared to the cost of conventional high quality concrete.

The constituent materials of SCC are: cement, mineral additions, aggregate, admixture and water.

The mineral additions improve and maintain the cohesion and segregation resistance, reduce the heat of hydration and thermal shrinkage, according to their reactive capacity with water they are classified: inert, pozzolanic and hydraulic.

The aggregate properties should be rigorously evaluated. The moisture content, water absorption, grading and variations in fines content of all aggregates should be closely supervised in order to produce SCC of constant quality. [4]

The shape and particle size distribution of the aggregate is very important and affects the packing and voids content.

The maximum aggregate size should generally be limited to 12 – 20 mm to avoid the aggregate blocking through the reinforcement.

Superplasticizers of high range water reducing admixtures are an essential component of SCC.

Choice of admixture for optimum performance may be influenced by the physical and chemical properties of the binder/addition.

Japanese professor H. Okamura and Ottawa presented the recommendations for the mix proportions of SCC, Fig. 1:

- -content of coarse aggregate is fixed at 50% of the total solid volume.
- -volume of fine aggregate should be 40% of the mortar volume.
- -water / powder ratio can be between 0.9... 1, depending on the characteristics of the powder and the superplasticizer dosage.

The required water /powder ratio should ensure the selfcompactibility.

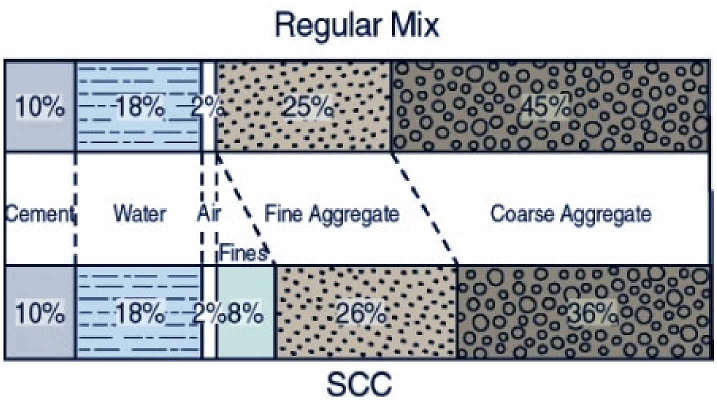

Fig. 1 *Composition of SCC versus vibrated concrete* [1]

3. Construction Labor

Plant's industrialization is essential to gain the benefit of modern technology and augment the level of economic prosperity. Construction industry still remains as one of the few homemade products put together piece by piece by workers, that's why it is one of the most labor-intensive industries in the world. The construction labor is a vital component of a building project that justifies its high costs, Fig. 2.

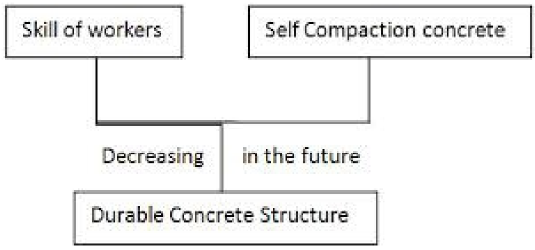

Fig. 2. *Necessity of SCC* [7]

Labor production rates are defined as a number of units of work produced in a specified time

Pouring concrete is a very complex process with high consumption of workmanship and can be divided into many more subprocess:

- cleaning the formwork;
- handling, horizontal and vertical transport of concrete to the desired location;
- casting of concrete;
- compacting and leveling concrete;
- providing work platforms for concrete's transport at casting places.
- supervision and required interventions to the formwork during the pour of concrete;
- control the quality and patching as needed.

The placing of workmanship is a major contributor to the quality of structures made with conventional concrete.

SCC was developed to reduce significantly the need of skilled labor due to elimination of mechanical compaction. It flows under its own weight and fills even intricate forming with dense rebar, Fig. 3.

Fig. 3. *Workers on pouring concrete*

The quality of concrete structures made of SCC nearly entirely depends on the quality of the concrete. Concrete manufacturers are not directly benefiting from the SCC technology, but the increased of responsibility for the quality of SCC demands tighter quality control measures and assurance of the quality.[6]

4. Equipment and Placement of Concrete

Modern construction is defined by the increasing utilization of equipment to accomplish numerous construction activities. Equipment refers to all the equipments, tools, and apparatus necessary for the proper construction and acceptable completion of a project. In a construction project, equipment costs are typically divided into portions. The first and bigger portion covers the cost of equipment and is often referred to as equipment cost. The second and smaller portion covers the cost of hand tools.

Placing concrete consumes a lot of

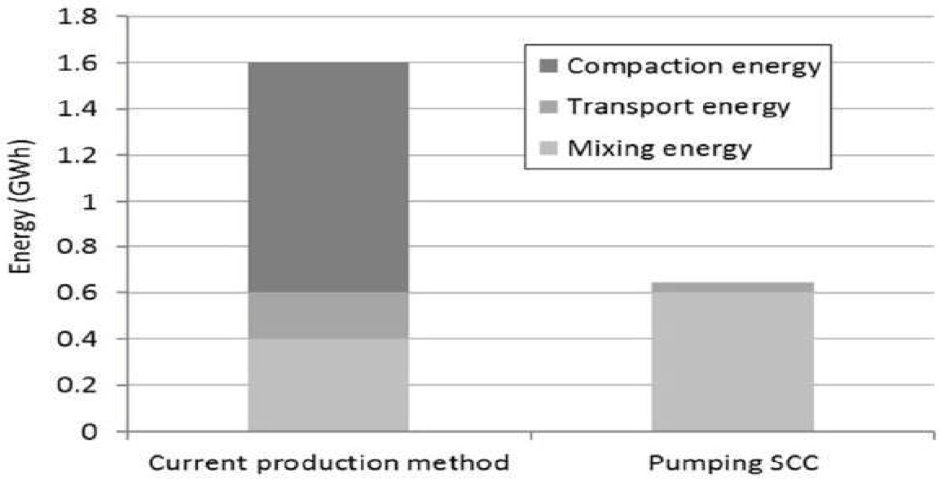

Fig.4. *Energy demand for producing and placing concrete* [9]

energy, includes increased utility rates, expensive and scarce skilled labor, rising material and equipment costs. SCC is a performing material of high fluidity that doesn't need any mechanical compaction to be placed.

SCC pumps easily with reduced pumping pressures. Air content tends to remain more stable in an SCC mix during pumping than in conventional concrete

The hydrostatic pressure of SCC is higher than that of conventional concrete and the formwork could need alteration to avoid the leak paste. The casting speed should be properly adjusted: pouring too rapidly may cause entrapped air and bug holes; pouring too slowly may lead to an insufficient head pressure, decreasing SCC's ability to fully compact in the form. To protect the surface from drying out is recommended to use an evaporation retardant where needed similar to conventional concrete mix.

5. Construction Time

Construction time represents the length of the period between the beginning of construction till its end and defines all the construction activities.

Casting concrete represents a complex process that requires skilled labor and affects the construction time. Its main activities are: placing, compaction, curing and demolding.

The vibration is the most common method of compacting of the concrete and represents a process of expelling the entrapped air. It has been found from the experimental studies that 1% of air in the concrete approximately reduces the strength by 3- 5%. The air voids increase concrete's permeability, reduce its durability and decrease the ability to withstand aggressive environment.

Curing is the protection of fresh concrete from evaporation and temperature extremes which might adversely affect cement hydration. The concrete must be protected from the harmful influences of wind, sun and variable weather to gain designed strength and durability.

Concrete elements can be demoulded as they attempt sufficient strength to take over all or part of load for which they were designed. The recommended values of

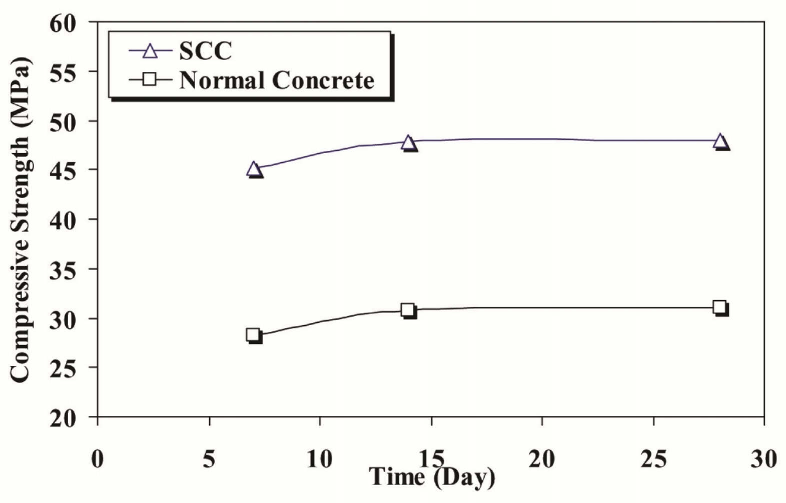

Fig. 5 *Compressive strength of SCC at early ages [8]*

minimum compressive strength which the element can be demoulded [4]:

- 2.5 N/mm^2 to remove the sides of formwork

-70-85% of designed strength to remove shuttering plates with maintaining safety props

SCC gave high values as for early strength (before 28 days) as for the entire curing duration compared to the normal concrete as shown in Fig. 3. The strength gained at 7 days was about of 90% percentage at 28-days strength for SCC and of 80% for normal concrete, while it was 96% for SCC at the age of 14 days. The duration of an activity may be estimated:

Work duration=quantity of work/number of crews x production rate

6. Cost of Construction

The total cost of a concrete structure depends of the expenses on labor, materials and equipment.

Labor costs are calculated by two factors: monetary and productivity.

The monetary factor itemizes the hourly wage rates, premiums, insurance and taxes. The productivity represents the quantity of work produced in a given amount of time by a worker or a special crew, that is the quantity of construction output units produced in a given amount of time or a unit time.Labor cost is determinate by multiplication the total labor hours by wage rate. It reduces with the increase of construction productivity. In a construction project, equipment costs are typically divided into portions: the cost of equipment and the cost of hand tools.

Equipment refers to all the equipment, tools, and apparatus necessary for the proper construction and acceptable completion of a project.

The cost per unit of time of each equipment has to be determined. Estimating equipment costs involves identifying the ownership and operating costs. Ownership costs include: initial cost, financing (investment) costs, depreciation costs and taxes and insurance costs.

The operating costs contain: maintenance and repair costs, storage costs, fuel and lubrication costs. According to the study made by Sue McCraven [9] in a plant, to determine the technical economic indicators of a product by cubic meter made with conventional mix and SCC. The results of the research are listed below:

The cost of labor of SCC was lower with 84;

material cost of SCC was higher with 18% by cubic meter,

the total time of casting SCC was shortened with 85%

The total cost for placing a product (labor + materials) by conventional concrete was higher than the cost by SCC with 8%.

Material costs are offset by labor economy.

7. Conclusions

The main technical economic indicators of a building are:

- total cost – labor, equipment, materials
- duration quantity/production per unit of time x number of crew
- unit cost - total cost/ quantity.

Based on this study, the following advantages of SCC used as a structural material may be described:

- depend less on skilled work force due to the elimination of vibration concrete
- placement at a faster rate due to the high workability of concrete mix.
- shortened construction periods as result of elimination of some technological processes as vibration, remedy pouring defects.
- reduced total cost of building due to diminish of labor, duration etc.

increase the safety by eliminating the need for consolidation.

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