

Experimental Study on Self-Compacting Concrete with various Percentage of Steel Fibres

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Abstract

Self-compacting concrete (SCC) represents one of the most outstanding developments in concrete technology since 1980s. At first developed in Japan in the late 1980s, SCC meanwhile is spread all over the world with a steadily increasing and varied number of applications. Due to its specific enhanced properties, SCC may contribute to a significant development of the quality of concrete structures and open up new fields for the application of concrete. Self-Compacting Concrete gets compacted and dense due to its self-weight. An experimental research has been carried out to determine different characters like strength and workability of Self-Compacting Concrete (SCC). Tests involving various fibre proportions for a particular mix of SCC were carried out. Test methods used to study the properties of fresh concrete were slump test, L-Box, U-Tube and V-Funnel. The properties like flexure, compressive and tensile strength of SCC were also investigated. Test Results shows that the workability characteristics of SCC are within the limiting constraints of SCC. The variation of different parameters of hardened concrete (M30 & M40) with respect to various percentage of steel fibre contents were analysed.

Keywords: Steel Fibres, Self-Compacting Concrete, SCC

I. INTRODUCTION

Development of self-compacting concrete (SCC) is a desirable achievement in the construction field in order to solve problems related with in-situ concrete. Self-Compacting concrete is not affected by the worker's skills, the shape and amount of reinforcing bars or the assemblage of a structure and, due to its high-flow ability and resistance to segregation it can be pumped longer distances. The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura (1997), but the prototype was first developed in 1988 in Japan, by Professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various research have been carried out and SCC has been used practically in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and self-compact ability testing methods have been carried out from the point of making it a standard concrete. Self-compacting concrete is used so that no additional inner or outer vibration is required for the compaction. It flows like "honey" and has a very smooth surface level after casting. With regard to its composition, self-compacting concrete consists of the same components as conventionally concrete which are cement, aggregates, and water, along with chemical and mineral admixtures in different proportions. Usually, the chemical admixtures used are high-range water reducers (superplasticizers) and viscosity-modifying agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. In this study, the cement content was partially replaced with mineral admixtures, e.g. fly ash, admixtures that improve the flowing and strengthening characteristics of the concrete.

II. LITERATURE REVIEW

Published literature on self-compacting concrete first appeared in 1989, and has been increasing significantly since that time, reflecting the amount of research and practical applications taking place. This chapter summarises the most important published information of direct relevance to the experimental work reported in this thesis. A significant amount of this is published in Japanese, and was translated by the author. Much was published during the course of the research, and in some cases, influenced the subsequent experimental work. To avoid unnecessary duplication, detailed information from some references is presented and discussed in later chapters together with results from the current programme.

A. Hajime Okamura

A new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamura (1997). In 1986, he started a research project on the flowing ability and workability of this special type of concrete, later called self-compacting concrete. The self-compact ability of this concrete can be largely affected by the characteristics of materials and the mix proportions. In his study, Okamura (1997) has fixed the coarse aggregate content to 50% of the solid volume and the fine aggregate content to 40% of the mortar volume, so that self-compact ability could be achieved easily by adjusting the water to cement ratio and superplasticizer dosage only.

A model formwork, comprised of two vertical sections (towers) at each end of a horizontal trough, was used by professor Okamura to observe how well self-compacting concrete could flow through obstacles. Figure 2.1 shows the ends of small pipes mounted across the horizontal trough and used as obstacles. The concrete was placed into a right-hand tower, flowed through the obstacles, and rose in the left-hand tower.

B. Kazumasa Ozawa

After Okamura began his research in 1986, other researchers in Japan have started to investigate self-compacting concrete, looking to improve its characteristics. One of those was Ozawa (1989) who has done some research independently from Okamura, and in the summer of 1988, he succeeded in developing self-compacting concrete for the first time. The year after that, an open experiment on the new type of concrete was held at the University of Tokyo, in front of more than 100 researchers and engineers. As a result, intensive research has begun in many places, especially in the research institutes of large construction companies and at the University of Tokyo.

Ozawa (1989) completed the first prototype of self-compacting concrete using materials already on the market. By using different types of superplasticizers, he studied the workability of concrete and developed a concrete which was very workable. It was suitable for rapid placement and had a very good permeability.

Other experiments carried out by Ozawa (1989) focused on the influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of self-compacting concrete. He found out that the flowing ability of the concrete improved remarkably when Portland cement was partially replaced with fly ash and blast furnace slag after trying different proportions of admixtures, he concluded that 10-20% of fly ash and 25-45% of slag cement, by mass, showed the best flowing ability and strength characteristics.

The obstacles were chosen to simulate the confined zones of an actual structure. The concrete in the left-hand tower rose to almost the same level as in the right-hand tower. Similar experiments of this type were carried out over a period of about one year and the applicability of self-compacting concrete for practical structures was verified. This research was started at the suggestion of professor Kokubu (Okamura, 1997) from Kobe University, Japan, one of the advisors of Hajime Okamura. They thought that it would be easy to create this new concrete because antiwashout underwater concrete was already in practical use. Antiwashout underwater concrete is cast underwater and segregation is strictly inhibited by adding a large amount of a viscous agent (antiwashout admixture), which prevents the cement particles from dispersing in the surrounding water. However, it was found that antiwashout underwater concrete was not applicable for structures in open air for two reasons: first, entrapped air bubbles could not be eliminated due to the high viscosity; and second, compaction in the confined areas of reinforcing bars was difficult. Thus, for the achievement of self-compact ability, a superplasticizer was indispensable. With a superplasticizer, the paste can be made more flow able with little concomitant decrease in viscosity, compared to the drastic effect of the water, when the cohesion between the aggregate and the paste is weakened

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Slump Test

Table - 1
Slump Flow Test Results (M30)

Steel Fibre %	0%	0.25%	0.50%	0.75%	1%
Slump Flow(mm)	780	760	725	705	700

Table - 2
Slump Flow Test Results (M40)

Steel Fibre %	0%	0.25%	0.50%	0.75%	1%
Slump Flow(mm)	740	685	690	650	625

B. U-Type Test

Table - 3
U-Box test results (M30)

Steel Fibre %	0%	0.25%	0.50%	0.75%	1%
U-Tube Filling Height	25	20	30	25	30

Table - 4
U-Box test results (M40)

Steel Fibre %	0%	0.25%	0.50%	0.75%	1%
U-Tube Filling Height	25	20	15	15	10

C. Combined Test Results of SCC with Different Steel Fibres Percentage

Table – 5
Combined Tabulated Results for different Percentage of Steel Fibres (M30)

Test Methods	SCC 0% SF	SCC 0.25% SF	SCC 0.5% SF	SCC 0.75% SF	SCC 1% SF
Slump Flow (mm)	780	760	725	705	700
T50 Slump Flow (mm)	5	5	5	4	4
V – Funnel Test (sec)	6	8	7	9	9
V – Funnel Test at T5 min(sec)	10	12	14	13	12
U-Box Test(mm)	25	20	30	25	30

Table - 6
Combined Tabulated Results for different Percentage of Steel Fibres (M40)

Test Methods	SCC 0% SF	SCC 0.25% SF	SCC 0.5% SF	SCC 0.75% SF	SCC 1% SF
Slump Flow (mm)	710	685	690	650	625
T50 Slump Flow (mm)	5	4	4	3	3
V – Funnel Test (sec)	6	8	8	9	10
V – Funnel Test at T5 min(sec)	10	12	14	11	12
U-Box Test(mm)	25	20	15	15	10

Table – 7
Comparison of compressive strength M30& M40 grade of concrete at 28 days strength

% of Steel Fibres Added	Compressive Strength at 28Days Curing (M30)N/mm ²	Compressive Strength at 28Days Curing (M40)N/mm ²
0%	28.5	45
0.25%	34	48
0.50%	38	52
0.75%	42	56
1%	47	60

IV. CONCLUSIONS

Taking into account the findings from this study, previously presented, the following conclusions can be drawn:

- It has been verified, by using the slump flow and U-tube tests, that self-compacting concrete (SCC) achieved consistency and self-compact ability under its own weight, without any external vibration or compaction.
- SCC has achieved a density between 2400 and 2500 kg/m³, which was greater than that of normal concrete, 2370-2321 kg/m³.
- Self-compacting concrete can be obtained in such a way, by adding chemical and mineral admixtures, so that its splitting tensile and compressive strengths are higher than those of normal vibrated concrete.
- An average increase in compressive strength of 12% has been obtained for different percentage of steel fibres, whereas 20% was the increase in splitting tensile strength.
- Also, due to the use of chemical and mineral admixtures, self-compacting concrete has shown smaller interface micro cracks than normal concrete, fact which led to a better bonding between aggregate and cement paste and to an increase in splitting tensile and compressive strengths.
- In addition, self-compacting concrete has two big advantages. One relates to the construction time, which in most of the cases is shorter than the time when normal concrete is used, due to the fact that no time is wasted with the compaction through vibration. The second advantage is related to the placing. As long as SCC does not require compaction, it can be considered environmentally friendly, because if no vibration is applied no noise is made.

The following points may be drawn out from the experimental study-

- From the test results of hardened concrete, it is been found that the all the mixes achieved the designed characteristic strength of M40 grade.
- Use of fly ash improve the setting characteristics of the SCC mix, but do not achieve the required flow properties of SCC. A VMA is required to achieve the flow.
- The compressive strength was conducted for all the different ratio of fibre mixes, it was found from the results that mix 5 (1% of fibres added) gives better strength.

The compressive strength of steel fibre has been increased up to 13.3%, 14.3%, 12%, 13%, 15% compared with M30 grade SCC.

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