[Blank 3 lines]

DEVELOPMENT, APPLICATIONS AND INVESTIGATIONS OF SELF-COMPACTING CONCRETE [14 points, Bold, centered]

[Blank 2 lines]

Masahiro OUCHI [Bold]
Kochi University of Technology, Japan
Makoto HIBINO
Nagaoka University of Technology, Japan
[Blank 5 lines]

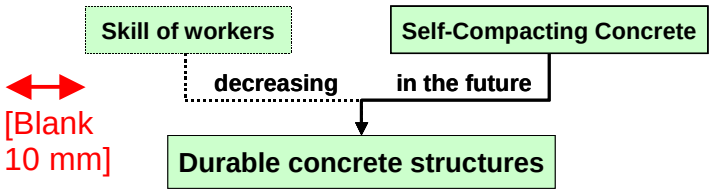
ABSRTACT [Bold]: Self-compacting concrete was first developed in 1988 so that durability of concrete structures can be improved. Since then, various investigations have been carried out and the concrete has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and self-compactability testing methods have been carried out from the viewpoint of making it a standard concrete. Recommendations and manuals for self-compacting concrete were also established. [Within 8 lines]
KEYWORDS [Bold]: self-compacting concrete, self-compactability testing method, mix-design method, srength development, heat generation [Within 2 lines]
[Blank 2 lines]

1. INTRODUCTION [Bold, CAPITAL]

[Blank 1 line]

1.1 Motive for Development of SCC [Bold]

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's construction industry has led to a similar reduction in the quality of construction work. One solution for the achievement of durable concrete structures independent of the quality of construction work is the employment of self-compacting concrete, which can be compacted into every corner of a formwork, purely by means of its own weight and without the need for vibrating compaction (**Fig. 1**) [Number of Figure: Bold]. The necessity of this type of concrete was proposed by Okamura in 1986. Studies to develop self-compacting concrete, including a fundamental study on the workability of concrete, were carried out by Ozawa and Maekawa at the University of Tokyo [1].



[Blank 10 mm]

Fig. 1 Necessity of SCC [Bold]

[Blank 2 lines]

[Blank 1 line between paragraphs]

1.2 Development of Prototype

The prototype of self-compacting concrete was first completed in 1988 using materials

already on the market. The prototype performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties. This concrete was named “High Performance Concrete.” and was defined as follows at the three stages of concrete.

[Blank 1 line]

At almost the same time, “High Performance Concrete” was defined as a concrete with high durability due to low water-cement ratio by Professor Aitcin. Since then, the term high performance concrete has been used around the world to refer to high durability concrete. Therefore, Okamura has changed the term for the proposed concrete to “Self-Compacting High Performance Concrete.”

[Blank 2 lines between chapters]

2. APPLICATIONS OF SELF-COMPACTING CONCRETE

Since the development of the prototype of self-compacting concrete in 1988, the use of self-compacting concrete in actual structures has gradually increased. The main reasons for the employment of self-compacting concrete can be summarized as follows:

(1) to shorten construction period
(2) to assure compaction in the structure: especially in confined zones where vibrating compaction is difficult
(3) to eliminate noise due to vibration: effective especially at concrete products plants

That means the current condition of self-compacting concrete is a “special concrete” rather than standard concrete. Currently, the percentage of self-compacting concrete in annual product of ready-mixed concrete in Japan is around 0.1% and 0.5% of concrete products (**Table 1**) **[Bold]** [2].

Table 1 Ratio of SCC in Japan [Bold]

10mm

	RMC	Products
1994	0.13	0.30
1998	0.10	0.50

[Blank 2 lines]

A typical application example of Self-compacting concrete is the two anchorages of *Akashi-Kaikyo* (Straits) Bridge opened in April 1998, a suspension bridge with the longest span in the world (1,991 meters) [3]. The volume of the cast concrete in the two ahchorages amounted to 290,000 m^3. A new construction system, which makes full use of the performance of self-compacting concrete, was introduced for this. The concrete was mixed at the batcher plant beside the site, and was the pumped out of the plant. It was transported 200 meters through pipes to the casting site, where the pipes were arranged in rows 3 to 5 meters apart. The concrete was cast from gate valves located at 5 meter intervals along the pipes. These valves were automatically controlled so that a surface level of the cast concrete could be maintained. In the final analysis, the use of self-compacting concrete shortened the anchorage construction period by 20%, from 2.5 to 2 years.

Self-compacting concrete was used for the wall of a large LNG tank belonging to the Osaka Gas Company, whose concrete casting was completed in June 1998 [3]. The volume of the self-compacting concrete used in the tank amounted to 12,000 m^3. The adoption of self-compacting concrete means that

(1) the number of lots decreases from 14 to 10, as the height of one lot of concrete casting was increased.

(2) the number of concrete workers was reduced from 150 to 50.
(3) the construction period of the structure decreased from 22 months to18 months.

Self-compacting concrete is often employed in concrete products to eliminate the noise of vibration [3]. This improves the working environment at plants and makes it possible for concrete product plants to be located in the urban area. The annual production of concrete products using self-compacting concrete exceeded 200,000 tons in 1996 [2].

3. INVESTIGATIONS ON SELF-COMPACTING CONCRETE

Various investigations have been carried out in order to make self-compacting concrete a standard one. The relative flow area Γc was defined as follows (Eq. 1):

[Blank 1 line]

[TAB]$\Gamma c = (Sfl^2 - 200^2) / 200^2$ (Eq.1)

[Blank 1 line]

The investigations were carried out at each university, large construction company and material maker. Committee activities were also carried out. As the result, Architectural Institute of Japan and Japan Society of Civil Engineers established “Recommendations for Mix Design and Construction Practice of Highly Fluidity Concrete” in 1997 and “Recommendation for Construction of Self-Compacting Concrete” in 1998 respectively. The national ready-mixed concrete industry association, Japan, established “Manual for Manufacturing of Self-Compacting Concrete” in 1998 [3].

4. CONCLUSIONS

It is considered that the main obstacles for making self-compacting concrete widely used have been solved. The next task in Japan is to distribute the technique for manufacturing and construction of self-compacting concrete rapidly. In addition, new structural design and construction systems making full performance of self-compacting concrete should be introduced.

[Blank 2 lines between the final chapter and references]

REFERENCES

[Blank 1 line]

1. Ozawa K., Kunishima, M., Maekawa, K. and Ozawa, K.: Development of High Performance Concrete Based on the Durability Design of Concrete Structures, Proceedings of the second East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC-2), Vol. 1, pp. 445-450, January 1989.
2. Ozawa, K. and Ouchi, M. (editor): Proceedings of the International Workshop on Self-Compacting Concrete, Kochi, March 1999.
3. Hayakawa M., et. al.: Development & Application of Super Workable Concrete, RILEM International Workshop on Special Concretes: Workability and Mixing, Paisley, 1993.
4. Okamura H., and Ozawa, K.: Mix-design for Self-Compacting Concrete, Concrete Library, JSCE, No. 25, pp.107-120, June 1995.