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Performance of Self-Compacting Concrete (SCC) Mixes with Different Brands of Superplasticizers

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Abstract— Self-Compacting Concrete (SCC), classified as High-Performance Concrete (HPC), is a type of cement-based concrete characterized by its high flowability, ability to compact without vibration, and resistance to segregation. These properties make SCC ideal for structures with dense reinforcement or complex cross-sections. The use of a Superplasticizer admixture is essential in producing SCC with the required performance. This study aimed to analyze the influence of three Superplasticizer brands—NAPTHA 600D, NORMET TanCem 60RP, and CONSOL P200-R 1S—on the characteristics and performance of SCC. The experimental work was conducted at the Laboratory of Geotechnics, Tunnels, and Structures (BGTS) of the Road and Bridge Engineering Implementation Unit. Three dosage variations (0.5%, 0.7%, and 1.0%) were tested to evaluate homogeneity, slump flow, and compressive strength. The slump flow was controlled according to the Bina Marga General Specifications 2018 Revision 2 (550–850 mm), and the compressive strength was targeted at 33 MPa at 7 days. The results showed that all Superplasticizers produced different flowability and strength characteristics. At 1.0% dosage, each brand achieved the required slump flow and compressive strength, with minor variations in homogeneity and bleeding behavior.

Keywords— Self-Compacting Concrete (SCC), Superplasticizer, Slump Flow, Compressive Strength, Concrete Homogeneity.

I. Introduction

A. Background

Cement concrete, as a type of construction material that is a mixture of cement, aggregate, and water, must meet three main technical criteria when manufactured, namely workability when fresh, strength when hardened at a certain age, and durability in maintaining strength over a certain planned service life. Concrete mixes can also use mineral additives or chemical additives (admixtures) if the concrete mix is required to have specific properties.

If a structure has a narrow cross-section with closely spaced reinforcement, or a structure with a complex shape that makes it difficult to cast so that it can fill the entire space in the structure homogeneously with maximum density, then a wet concrete mix with very high workability is required [1]. Currently, concrete with these properties is known as Self Compacting Concrete (SCC), which has the special characteristics of being highly plastic (flowing) and capable of self-compacting, without segregation and without the use of compacting tools (vibrators) as commonly used to compact conventional concrete mixes. With these unique properties, SCC is classified as High Performance Concrete (HPC) in terms of performance [2]. SCC has very significant differences in both the way the material proportions are designed and in the way it is controlled compared to conventional or ordinary concrete, so to ensure the quality of SCC concrete, competent human resources are required as mix designers, implementers, and supervisors to avoid errors in implementation [3].

The use of Superplasticizer admixtures is essential to achieve SCC. In practice, there are quite a number of Superplasticizer brands on the market, so the results of this study, which show that Superplasticizers of different brands can have different effects on the characteristics and performance of SCC concrete mixes, are expected to help SCC concrete implementers in selecting effective and efficient Superplasticizers according to the requirements of the SCC concrete to be worked on [4].

B. Problem Statement

The research questions related to the above research title are:

1. How significant is the effect of using Superplasticizer in the manufacture of SCC concrete?
2. What are the performance/properties of SCC concrete mixes that use Superplasticizer with the same dosage but different brands?

C. Research Objectives

This study aims to determine the performance/properties of concrete mixes using the same dosage of different brands of superplasticizers.

D. Benefits of Research

Due to the large number of Superplasticizer products from different manufacturers, the results of this study are expected to provide important information for concrete contractors, especially SCC concrete contractors, to obtain SCC concrete that meets quality criteria through the effective and efficient use of Superplasticizer.

E. Scope of the Problem

The scope of this study is limited as follows:

1. The target strength is f'c 33 MPa
2. Three brands of superplasticizers are used, namely NAPTHA 600D, NORMET TanCem 60RP, and CONSOL P200-R 1S
3. The dosage variants for each superplasticizer are 0.5%; 0.7%; 1.0%
4. The main performance parameters of the concrete mix studied are homogeneity, consistency, concrete bulk density when fresh, and the strength of hardened concrete cylinders at 7 days of age.

II. LITERATURE REVIEW

Self-compacting concrete is concrete that has high flowability, does not segregate, and can spread into place, fill the formwork, and fill the gaps between reinforcement without mechanical compaction (ACI PRC-237-07-2019: Self-consolidating concrete (SCC) is highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation) [5].

The concept of SCC was first introduced in 1986 by Prof. Okamura at Kochi University in Japan, at a time when limited labor availability was causing difficulties in the concrete industry [6]. The first generation of SCC was used in North America, which used relatively high cement content and also used relatively high doses of superplasticizer additives to improve the flowability and stability of fresh concrete mixes [7]. With its performance, SCC is the right solution for casting work in narrow spaces or cross-sections, or complex structural shapes with dense reinforcement that makes it difficult to access to compact the concrete with a vibrator [8].

Another advantage of using SCC is that the concrete mix is easy to pump when using a concrete pump, reducing the number of workers required and reducing noise levels in the workplace [9]. The use of supplementary cementitious materials and fillers can increase the paste volume and also improve the deformability, cohesiveness, and stability of the concrete. The use of fly ash or other materials such as silica fume can reduce the cement content, water-cement ratio, and superplasticizer dosage [10].

In the manufacture of SCC concrete, the use of superplasticizer admixtures is essential to obtain a flowing concrete mix. Superplasticizers, which according to the definition of ACI 212.3R are also known as High Range Water Reducers (Type F), are water-soluble organic compounds which, when used in concrete mixtures, can reduce water requirements by a high range (25% to 30%) while producing a highly plastic (flowing) concrete mixture without segregation or blinding [11]. The dosage of Superplasticizer is usually 0.5% - 3% of the cement weight according to requirements. The use of Superplasticizer below the minimum dosage will not form SCC concrete, while its use above the maximum dosage will cause SCC concrete to be damaged; segregation and blinding. Figure 1 below shows the effect of using Superplasticizer on reducing water usage, increasing workability, and improving concrete quality [12].

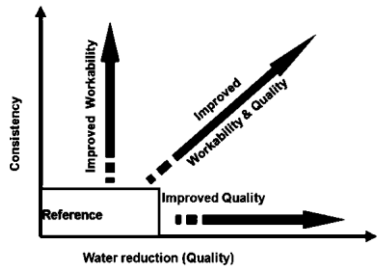

Figure 1. Effect of *Superplasticizer* on *workability* and concrete quality
Source: Solusi Beton Ready-Mix Website

In general, superplasticizers used in the construction industry can be classified as follows:

1. Polycarboxylate Ether (PCE)
   This type of superplasticizer is known for its excellent dispersibility, making it ideal for high-strength concrete and concrete mixes with low water-cement ratios.
2. Naphthalene Sulfonate
   This type of superplasticizer is more commonly used and offers significant workability improvement, although it may not be as effective as PCE in some specialized applications.

There have been many studies related to the use of superplasticizers in SCC mixtures, including:

1. Risdianto, Y. (2010), "Penerapan Self Compacting Concrete (SCC) pada beton mutu normal" Jurnal Teknik Waktu, 8(2), 54–58. In this study, several mixture tests were conducted to determine the effect of using Conplast SP430 additives on the characteristics of normal concrete with a fine aggregate/coarse aggregate ratio of 0.60/0.40.
2. Ngudiyono, N., Merdana, I. N., Mahmud, F., & Fajrin, J. (2021), "Kajian eksperimental kuat lekat tulangan beton memadat sendiri (Self Compaction Concrete)", SAINTEK Proceedings, 3, 328–338. Mataram University. The focus of the experimental research by Ngudiyono, N., Merdana, I. N., Mahmud, F., & Fajrin, J. (2021) is on the bond strength

properties of SSC concrete with one superplasticizer product on different types of steel reinforcement surfaces (smooth and threaded)

3. Ashish Kumar & Gaurav Kumar, 2018, "A Mix Design Procedure for Self-Compacting Concrete", International Research Journal of Engineering and Technology (IRJET). The research was experimental in nature on several mix proportions with variations in the fine aggregate/coarse aggregate ratio, water/cementitious ratio, and brand and dosage of Superplasticizer (Conplast SP430) for a specific mineral additive content.

III. RESEARCH METHODOLOGY

The research study was experimental in nature, involving concrete mixing experiments in the laboratory, which included the following main activities:

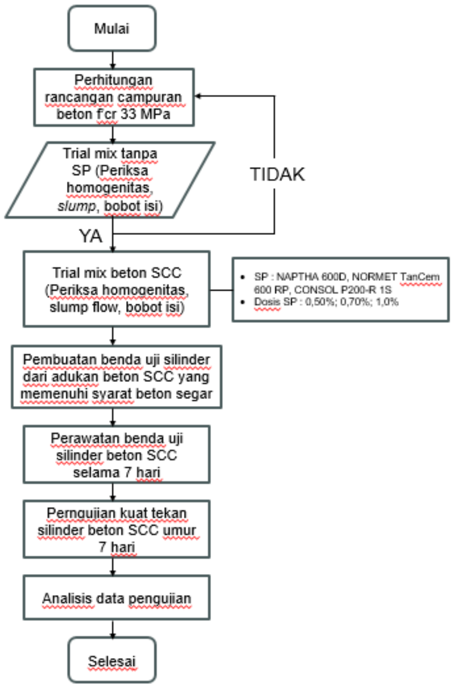

Figure 2. Research flowchart of Self-Compacting Concrete (SCC) testing in the laboratory

1. Concrete mix design based on material testing data available at the Tunnel and Structure Engineering Laboratory (BGTS) of the Road and Bridge Technical Center [8];
2. Calculation of concrete mix design was carried out using the SNI 03-2834-2000 method;
3. Concrete consistency (slump) testing without Superplasticizer was carried out in accordance with SNI 1972: 2022;
4. SCC concrete slump flow testing was carried out in accordance with SNI 9024:2021;
5. For the purpose of testing the compressive strength of each concrete mix, three 150-300 mm concrete cylinder test specimens were made;
6. The compressive strength testing of the concrete cylinder test specimens was carried out in accordance with SNI 1974: 2011.

III. RESULT AND DISCUSSION

A. Material Properties

The material composition for this mixture consists of Type I Ordinary Portland Cement. The coarse aggregate is characterized by a maximum particle size of 12.5 mm, a Saturated Surface Dry (SSD) specific gravity of 2.53, and a water absorption of 1.5%. The fine aggregate is defined as material that passes a #4 sieve and possesses an SSD specific gravity of 2.56 with a water absorption of 2.5%. After that with the Superplasticizer: NAPTHA 600D, NORMET TanCem 60RP, CONSOL P200-R 1S.

B. Planned Concrete Quality and Proportions of the Proposed Mix Design

This concrete mix design is engineered to achieve specific planned qualities and proportions. The primary target is to reach an average compressive strength (f'c) of 33 MPa at 7 days, utilizing a specified water-cement ratio of 0.43. This mixture is formulated to produce a normal concrete slump within the range of 30 to 60 mm to ensure appropriate workability. The normal concrete mix proportions per cubic meter are as follows: 195 kg/m³ of water, 453 kg/m³ of cement, 831 kg/m³ of fine aggregate, and 831 kg/m³ of coarse aggregate. This combination results in a total wet concrete weight of 2310 kg/m³. Thus, the design effectively balances the target strength, workability, and the planned material proportions.

C. Results and Discussion of Fresh Concrete Performance

The recommended use of concrete superplasticizers by each manufacturer may vary within a minimum-maximum range [13]; the use of superplasticizers at doses below the minimum may not have a significant effect, while the use of doses above the maximum may cause the concrete mix to be completely damaged. SCC mix testing was conducted by taking variations of Superplasticizer doses of 0.50%; 0.70%, and 1.0% for each of the three Superplasticizer brands used [7].

Table 1. Fresh Concrete Properties of SCC with Various Superplasticizers

Superplasticizer Brands and Types	Dosage (%) Relative to Cement Weight	Slump/Slump Flow	Homogeneity	Fresh Concrete Weight (kg/m3)
Without Superplasticizer	-	Slump 38 mm (design 30-60 mm: compliant)	Fulfilling	2286 (99%x2310: meets)
NAPTHA 600D	0,5	Flow 320 mm (Does not meet requirements)	Not checked	Not checked
	0,7	Flow 450 mm (Does not meet requirements)	Not checked	Not checked
	1,0	Flow 630 mm (Compliant)	Good homogeneity (Compliant)	2310 (100%x2310: fulfilled)
NORMET TanCem 60RP	0,5	Flow 630 mm (Compliant)	Good homogeneity (Compliant)	2315 (100.2% x 2310: fulfilled)
	0,7	Flow 680 mm (Compliant)	Not homogeneous & blinding (Does not meet requirements)	Not checked
CONSOL P200-R 1S	0,5	Flow 300 mm (Does not meet requirements)	Not checked	Not checked
	0,7	Flow 460 mm (Does not meet requirements)	Not checked	Not checked
	1,0	Flow 700 mm (Compliant)	A little segregation and blinding (still acceptable)	2300 (100%x2310: fulfilled)

- The flow value obtained is compared with the slump flow requirements according to the 2018 Revised General Specifications for Highways: (550 – 850) mm.
- The wet concrete density test is carried out on concrete mixes without Superplasticizer and on concrete mixes with Superplasticizer when the required flow is achieved. Estimated design density = 2310 kg/m3

Note: No trial mix was conducted for NORMET 1.0% because the mixture would definitely segregate and cause severe blinding. With the Superplasticizer CONSOL P200-R 1S, a flow that meets the requirements with good homogeneity and no blinding will be obtained at a specific dosage of > 0.7% and <1.0%.

Figure 3. SCC with 1.0% NAPTHA 600D Superplasticizer

This specific evaluation is part of a trial mix, as indicated by the sign, which documents the key variable under investigation: the superplasticizer (SP). The concrete mixture shown was produced using the NAPTHA 600D brand of superplasticizer at a dosage of 1.0%. The measurement of the spread's diameter, currently being performed with a measuring tape, is a critical procedure to quantitatively assess the concrete's flowability and self-consolidating properties [14]. This data provides a direct measure of the admixture's effectiveness in achieving the high degree of fluidity required for SCC, ensuring the mix can spread and fill formwork without segregation or bleeding [15].

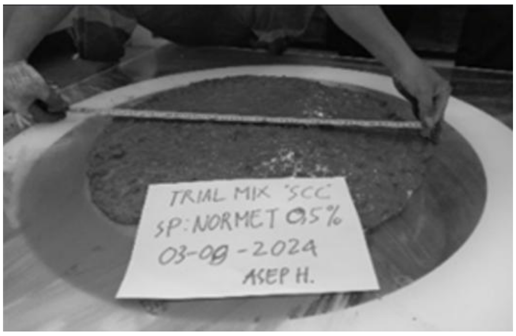

Figure 4. SCC with NORMET TanCem 60RP Superplasticizer 0.5%, flow 630 mm, good homogeneity

As documented by the sign and caption, this specific trial mixture incorporates the NORMET TanCem 60RP brand of superplasticizer at a dosage of 0.5%. The ongoing measurement of the spread diameter is a critical test to evaluate the concrete's ability to flow and consolidate under its own weight without vibration. The mixture achieved a flow diameter of 630 mm, indicating excellent fluidity. Furthermore, the concrete is noted to exhibit good homogeneity, which means the components are evenly distributed without any signs of segregation [16]. This outcome demonstrates the effectiveness of this particular superplasticizer at the specified dosage in producing a stable, highly workable SCC mix that meets key performance criteria for flow and consistency.

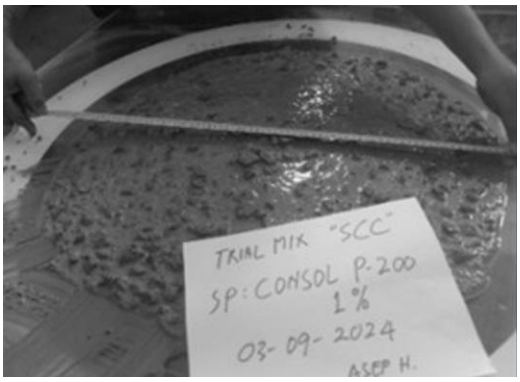

Figure 5. SCC with CONSOL P 200-R 1S Superplasticizer, 1.0%, slight segregation % blinding

With the above results, it is clear that the three brands of Superplasticizer used at doses starting from 0.5% are capable of transforming normal concrete with a small slump of 3.8 cm into flowing concrete without adding water [17]. It can also be seen that each brand achieves flow that meets the specification requirements with different flow values and actual mix conditions at different doses. In terms of concrete density, the data shows that the use of Superplasticizer can make concrete more dense compared to concrete without Superplasticizer [18].

Table 2: Results of SCC Concrete Cylinder Compressive Strength Test

Brand; Type of Superplasticizer; Dosage	Cylinder No.	Cylinder Weight (kg)	Average Cylinder Weight (kg)	Cylinder Compressive Strength at 7 days (MPa)	Average Compressive Strength (MPa)
NAPTHA;600D;1 %	1	12,48	12,53	36,16	35.17 (>33 MPa: Compliant)
	2	12,55		35,23	
	3	12,56		34,11	
NORMET; NORMET TanCem 60RP; 0.5%	1	12,29	12,28	31,71	33.12 (> 33 MPa: Compliant)
	2	12,28		33,42	
	3	12,27		34,24	
CONSOL; P200-R 1S;1.0%	1	12,23	12,16	38,53	36.46 (>33 MPa: Compliant)
	2	12,09		34,40	

Note: Average strength values are compared to the design average strength target of 33 MPa. For SCC with CONSOL 1.0%, only two cylindrical test specimens met the physical conditions for testing.

Overall, the SCC mixtures using each brand of superplasticizer tested produced cylinder compressive strengths that exceeded the target compressive strength (33 MPa) [19]. The different compressive strength values (35.17 MPa, 33.12 MPa, 36.46 MPa) indicate that each brand of superplasticizer used has a relatively different self-compacting ability [20].

IV. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

Self-Compacting Concrete (SCC) is fundamentally distinct from conventional concrete, differing not only in its mixture characteristics but also in its design methodology, implementation, and testing procedures. The primary factor in achieving the unique properties of SCC is the use of a Type F Superplasticizer additive, which, when combined with a specific aggregate gradation and a controlled water-cement ratio, enables the concrete to flow and consolidate under its own weight. It is crucial to recognize that utilizing different brands of these

Type F superplasticizer admixtures, even within an otherwise identical mixture, can lead to significant variations in the characteristics of both the fresh and hardened SCC.

Consequently, producing SCC that meets specific performance criteria, such as desired flowability, homogeneity, and resistance to segregation and bleeding, is not a straightforward process. The variability introduced by different superplasticizer brands necessitates a rigorous and empirical approach to mix design. Therefore, achieving a successful and reliable SCC mixture is only possible through the execution of sufficient trial mixes, which must be carried out in a controlled setting, either in a laboratory or at the batching plant. This iterative testing process is essential to calibrate the proportions and select the appropriate admixture to ensure the final product performs as intended without defects.

B. Recommendations

Considering that SCC is not ordinary concrete and its use in construction is becoming increasingly widespread, it is necessary to prepare competent human resources related to SCC concrete, both as mix designers, implementers, and supervisors to avoid errors in implementation.

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