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Influence of Polymer Superplasticizers Usage on Workability and Compressive Strength of 30 MPa and 40 MPa Concrete

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ABSTRACT

The advancement of technology has provided various alternatives to address limitations in concrete construction. One effective method for enhancing the quality of concrete is by introducing additional materials, known as admixtures, during the concrete production phase. One such type of admixture that can significantly improve concrete quality is superplasticizer. The primary principle behind the use of superplasticizer is to create a repelling force between cement particles to prevent clumping, which can lead to the formation of air voids in the concrete. This, in turn, can reduce the strength or quality of the concrete. In this research, the focus will be on the use of concrete admixtures, specifically superplasticizer, to enhance concrete workability. One product of superplasticizer is Sika Viscocrete 3115 N, which will be used in this study. Superplasticizers like Sika Viscocrete 3115 N play a crucial role in improving the flow and workability of concrete mixes, making them easier to handle and place during construction. This leads to more efficient and high-quality concrete structures. The target compressive strengths are 30 MPa and 40 MPa with variations in the percentage of superplasticizer admixture usage at 0%, 0.25%, 0.5%, and 0.75%. The testing methods used to determine the workability value are the slump test and the slump flow test, while the compressive strength test is conducted using a compression testing machine at the Advanced Concrete Materials and Computational Mechanics Laboratory, Department of Civil Engineering, ITS. The study concludes that the addition of superplasticizer can enhance the workability of concrete but cannot optimally increase compressive strength. Additionally, different planned compressive strengths with the same percentage variation exhibit different trends. The addition of 0.25%-0.5% superplasticizer in both planned strengths still yields compressive strength above the planned levels, despite the decrease.

Keywords: *self compacting concrete; additive; polymer; viscocrete.*

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ABSTRACT

Kemajuan teknologi telah mengembangkan berbagai alternatif untuk mengatasi kekurangan dalam konstruksi beton. Salah satu metode yang dapat digunakan untuk meningkatkan kualitas beton adalah dengan memperkenalkan bahan tambahan (admixture) selama tahap produksi beton. Salah satu jenis bahan tambahan yang dapat memberikan peningkatan signifikan dalam kualitas beton adalah superplasticizer. Prinsip utama dari penggunaan superplasticizer yaitu menghasilkan gaya tolak menolak antar partikel semen agar tidak terjadi penggumpalan yang dapat menyebabkan adanya rongga udara dalam beton sehingga dapat menyebabkan turunnya nilai kekuatan atau mutu beton. Dalam penelitian ini akan dilakukan penelitian terkait penggunaan admixture beton, yakni superplasticizer yang menambah workability beton. Salah satu produk bahan superplasticizer yakni Sika Viscocrete 3115 N yang akan digunakan dalam penelitian ini. Adapun mutu rencana beton 30 Mpa dan 40 Mpa dengan variasi prosentase penggunaan admixture superplasticizer sebesar 0%, 0,25%, 0,5%, dan 0,75%. Metode pengujian yang dilakukan untuk mengetahui nilai workability yakni dengan tes slump dan tes slump flow, sedangkan pengujian kuat tekan dilakukan tes kuat tekan menggunakan alat uji tekan di Lab. Beton Material Maju dan Komputasi Mekanik, Departemen Teknik Sipil ITS. Berdasarkan penelitian, maka didapatkan kesimpulan bahwa penambahan superplasticizer dapat menambah workability beton, namun tidak dapat menaikkan kuat tekan beton secara optimum, pada mutu kuat tekan yang berbeda dengan variasi prosentase sama akan memiliki tren yang berbeda. Penambahan superplasticizer 0,25%-0,5% pada kedua kuat tekan rencana masih menghasilkan kuat tekan diatas kuat tekan rencana meskipun terjadi penurunan.

Keywords: *self compacting concrete; zat adiktif; polimer; viscocrete.*

INTRODUCTION

Modern infrastructure innovates in line with the requirements for the durability of concrete materials. This drives the development of concrete that not only possesses high strength but is also capable of enduring for extended periods, even under extreme environmental conditions [1]. The development of concrete technology as a construction material has been extensively pursued to enhance its quality from various perspectives, including workability, setting time, compressive strength, and other aspects to support the characteristics of concrete material. The proportion and selection of materials or aggregates that constitute it can improve the quality of concrete, ultimately leading to high-quality concrete [2][3]. The issues frequently encountered in the concrete casting process that affect the compressive strength of concrete are porosity, caused by particles in the concrete mixture with larger dimensions, resulting in suboptimal density. Additionally, porosity can be attributed to the Water-to-Cement Ratio. The Water-to-Cement Ratio is the ratio of the weight of water to the weight of cement. The lower the water-to-cement ratio, the higher the compressive strength [4]. Workability in concrete is required for casting elements with a high percentage of reinforcement and closely spaced reinforcement, such as beams, columns, slabs, beam-column connections, plates, and composite structural elements (concrete-steel) [5]. The resulting impact is segregation, which is the separation between fine aggregate, cement, and water from coarse aggregate. To address this issue, concrete technology has been developed, including the development of Self-Compacting Concrete (SCC)[6]. Self-Compacting Concrete, or SCC, is a concrete mix that has the ability to achieve compaction without relying on compaction tools, resulting in a relatively high slump value. Instead, compaction is achieved through the use of additional materials such as additives or superplasticizers. The use of SCC in precast concrete production processes can enhance efficiency and reduce production time and costs [7][6][8].

Superplasticizer is a high-range water-reducing additive (HRWR), categorized as a Class F chemical admixture according to the classification in SNI 03-2495-1991 [9]. This additive is used to improve the slump value and strength of concrete, creating concrete that is easily workable without the need to add excessive water, which could lead to bleeding or segregation. Superplasticizer contains sulfonate components that play a role in reducing surface tension on cement particles, allowing for more even dispersion of cement particles and reducing the amount of water bound to the cement particles. This results in lower viscosity in the fresh cement or concrete mix. The required dosage will vary depending on the dosage recommendations provided by the superplasticizer manufacturer [10]. According to [11], the maximum limit for the superplasticizer content is 1.4% of the weight of cement. In the study [12], the use of polycarboxylate superplasticizer with superplasticizer percentages of 0.5%, 1%, 1.5%, and 2% relative to the cement proportion resulted in an increase in the slump value by 100%, 183%, 216%, and 507%, respectively. Meanwhile, in the study [13], using the same type of superplasticizer as in study [12], variations in the addition of superplasticizer at 0.3%, 0.5%, and 0.7% resulted in increases of 17%, 100%, and a decrease in the 0.7% addition variation to 64.71%. This reduction is caused by the addition of a significant amount of superplasticizer to the concrete mix, leading to a decrease in the required water content.

The advancement of technology has developed various alternatives to address deficiencies in concrete construction. One method that can be employed to enhance the quality of concrete is by introducing additives (admixture) as superplastisizer during the concrete production stage. Admixtures are crucial components widely used in buildings, bridges, dams, and other fields as they can significantly improve workability, compaction ability, binding properties, and material volume stability[14]. One type of additive that can provide a significant improvement in the quality of concrete is superplasticizer. The main principle of using superplasticizer is to generate repulsive forces between cement particles to prevent clumping, which could lead to the formation of air voids in concrete, potentially reducing its strength or quality[13]. Superplasticizer can reduce water content by up to 30% from the initial concrete mix and is necessary to maintain the slump value of the concrete [15]. Another advantage of using superplasticizer is preventing corrosion on concrete reinforcement caused by concrete compaction, improving concrete workability, and making concrete more water-resistant [10][16][17]. Weakness of using superplasticizer is the rapid reduction in slump, so even though workability increases significantly, the working time becomes shorter (setting time). Within one hour of using superplasticizer, workability will decrease due to the rapid hardening process [13]. Several studies have been conducted on the addition of superplasticizer, focusing on the compressive strength results of concrete. The conducted research [15] using Sika products as an admixture with variations in additions of 0.3%, 0.6%, 0.9%, and 1.2%, the optimum result was obtained with an addition variation of 0.3%, showing an increase in compressive strength by 17.84%. In the conducted research [16] using Ligno C-165 type superplasticizer with variations in additions of 0.25%, 0.5%, 0.75%, 1%, 1.25%, and 1.5%, the planned strength in this study is 40 MPa. The optimum compressive strength result was obtained at a superplasticizer percentage of 1.5%, showing an increase of 47.66% compared to normal concrete compressive strength.

In this research, a study will be conducted regarding the use of concrete admixture, namely superplasticizer, to enhance concrete workability. One product of superplasticizer is Sika Viscocrete 3115 N, which will be utilized in this study. The planned strength of the concrete is 30 MPa and 40 MPa with varying percentages of superplasticizer admixture at 0%, 0.25%, 0.5%, and 0.75%. This study will examine several parameters, including slump value, slump flow, and concrete compressive strength. The compressive strength of concrete will be evaluated at 28 days. This research aims to create concrete that can flow naturally without the need for mechanical compaction processes. The purpose of this research is to develop more efficient construction materials, enhance the strength and durability of concrete, and improve construction productivity by reducing the time and labor required for the casting process. These advancements aim to be applied in construction activities, particularly in on-site concrete casting.

METHOD

The various steps of this research were illustrated in a flowchart to ensure that the study remained focused and aligned with the research problem and objectives. In this chapter, several aspects of the research were detailed extensively to facilitate the progress of the study. The research flowchart can be seen in Figure 1.

Concrete Mix Design

This step involved planning the composition of the concrete mix by determining the percentage of cement, sand, and crushed stone according to the planned compressive strength of the concrete. The concrete mix design conformed to SNI 03-2834-2000 with planned strengths of 30 MPa and 40 MPa, and variations in superplasticizer addition at 0%, 0.25%, 0.5%, and 0.75% by weight of cement. In this study, Sika Viscocrete superplasticizer, Sika brand, type 3115N, was used. As for the proportion of superplasticizer can be seen in Table 1.

Table 1. Proportion of Superplasticizer (Mix Design SCC)

Compressive Strength (Percentage of Superplasticizer)	Superplasticizer Proportion (gr/cm^3)
30 MPa (0%)	0
30 MPa (0.25%)	27.81
30 MPa (0.5%)	55.61
30 MPa (0.75%)	83.42
40 MPa (0%)	0
40 MPa (0.25%)	32.78

Compressive Strength (Percentage of Superplasticizer)	Superplasticizer Proportion (gr/cm³)
40 MPa (0.5%)	65.56
40 MPa (0.75%)	98.34

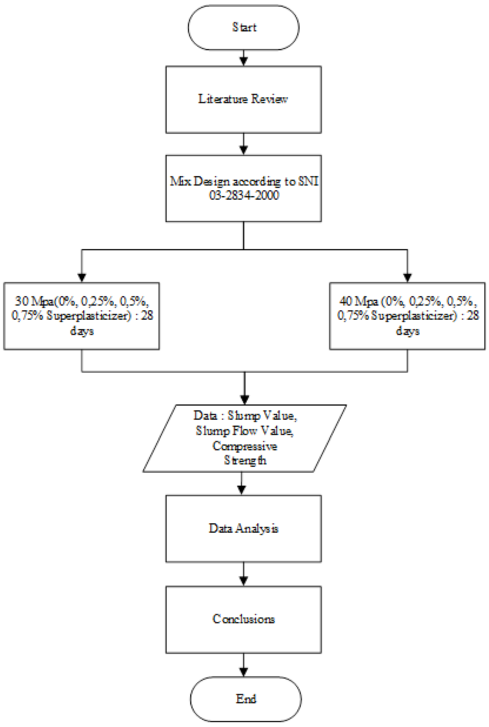

Figure 1. Flowcharts diagram

Concrete Cylinder Specimens

The specimens used were in the form of cylinders with dimensions of 10x20 for each planned strength. Documentation of the specimen preparation can be seen in Figure 2.

Figure 2. Cylinder Specimen

Slump Test

This step aimed to determine the consistency of fresh concrete, where the slump value affected the quality and workability of concrete. In this study, the planned slump value was in the range of 60-180 mm. This value was set based on the conditions of the work implementation to produce easily workable concrete. One of the additives used in this study was superplasticizer. The addition of such additives was accompanied by a reduction in water to achieve better concrete strength [18]. Documentation of the concrete slump test can be seen in Figure 3.

Figure 3. Slump Test of Concrete

Slump Flow Test

The slump flow test aimed to assess the extent to which concrete could fill a space (Filling Ability). This evaluation was based on the diameter of the circle formed by the concrete mix, which was used to measure its filling ability. The testing technique using a slump cone was a simple, fast, and practical method for field applications. However, this method could not identify how well concrete could avoid segregation. The slump cone test was highly beneficial for maintaining the consistency of the planned and prepared concrete mix. During the slump cone test, there were specific limitations indicating that a concrete mix fell into the category of Self-Compacting Concrete (SCC) and met the criteria for good filling ability when the concrete mix could achieve a diameter of 50 cm. [19].

Figure 4. Slump Flow Test of Concrete

Compressive Strength Test

In this step, testing was conducted on specimens to determine the compressive strength of concrete at a specimen age of 28 days. The testing was performed at the Advanced Concrete and Mechanical Computation Material Laboratory, Department of Civil Engineering, ITS.. Documentation of the testing can be seen in Figure 5.

Figure 5. Compressive Strength Test of Concrete

Data Analysis

After collecting the required data comprehensively, the data was processed and analyzed utilizing the literature obtained and the test results. The equation used in the analysis of concrete compressive strength of concrete and standard deviaton from several specimens can be determined by equation 1 and equation 2 [20].

$$f'c = \frac{P}{A} \quad \text{. …. (1)}$$

Where :

f'c : Concrete Compressive Strength (MPa)
P : Ultimate Load (N)
A : Area Section of Specimen (mm²)

$$S = \sqrt{\frac{\sum_{i=1}^{n}(fci - fcr)^2}{n-1}} \quad \text{. …. (2)}$$

Where :

S : Standard Deviation (MPa)
fci : Concrete Compressive Strength (MPa)
fcr : Average of Concrete Compressive Strength (MPa)
n : Number of Specimens

RESULTS AND DISCUSSION

Slump Value and Slump Flow Value

The concrete slump test values determine the workability of the concrete. According to the requirements, the concrete slump value must meet the criteria with a range of 75 mm – 100 mm. In this study, the evaluation is focused on the strengths of 30 MPa and 40 MPa with various additions of superplasticizer. The results of the slump test are presented in Table 2.

Table 2. Slump Value

No.	Compressive Strength (Proportion of Superplasticizer)	Slump Value (mm)	Requirement
1	30 MPa (0%)	25	unqualified
2	30 MPa (0.25%)	40	unqualified
3	30 MPa (0.5%)	90	qualify
4	30 MPa (0.75%)	100	qualify
5	40 MPa (0%)	40	unqualified
6	40 MPa (0.25%)	50	unqualified
7	40 MPa (0.5%)	55	unqualified
8	40 MPa (0.75%)	75	qualify

Based on Table 2, it can be concluded that the use of Sika Viscocrete superplasticizer can enhance the workability of concrete. According to the data in Table 1, for a strength of 30 MPa, the use of 0.5% and 0.75% Viscocrete meets the required slump values, while for a strength of 40 MPa, the use of 0.75% Viscocrete fulfills the specified slump value. Further discussion will address the slump flow values as shown in Table 3.

Table 3. Slump Flow Value

No.	Compressive Strength (Proportion of Superplasticizer)	Slump Flow Value (cm)	Requirement
1	30 MPa (0.25%)	40	unqualified
2	30 MPa (0.5%)	55	qualify
3	30 MPa (0.75%)	57	qualify
4	40 MPa (0.25%)	33	unqualified
5	40 MPa (0.5%)	52	qualify
6	40 MPa (0.75%)	65	qualify

Based on the results shown in Table 3, data on the slump flow values for various percentages of superplasticizer addition were obtained. This is crucial in determining whether the mix design can be categorized as self-compacting concrete or not. The data in Table 2 indicates that concrete with strengths of both 30 MPa and 40 MPa, with the addition of 0.5% and 0.75% superplasticizer, qualifies as self-compacting concrete.

Compressive Strength

Concrete compressive strength testing is a destructive method used to measure the hardness of concrete. The purpose of this test is to assess the compressive strength of concrete at each desired age of concrete. In this study, trials were conducted to ensure that the mix design meets the planned strength. If it does not meet the criteria, a redesign of the mix will be performed until the target strength is achieved. Two planned strengths were compared in this study, namely 30 MPa and 40 MPa. After the normal concrete mix design meets the planned strength criteria, superplasticizer is used with various percentage additions, namely 0.25%, 0.5%, and 0.75% for each strength. The results can be seen in Figure 6 and Figure 7.

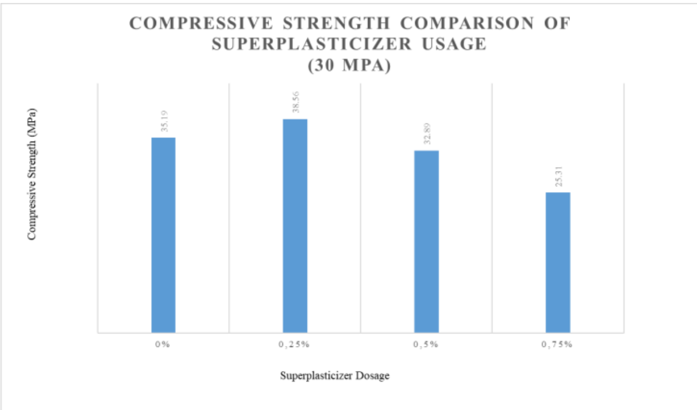

Figure 6. Compressive Strength of 30 MPa Concrete with Various Percentages of Superplasticizer

Based on Figure 6, results for the planned 30 MPa concrete quality were obtained, where there is an increase in compressive strength with the addition of superplasticizer at a percentage of 0.25%, resulting in a 10% increase in compressive strength. Subsequently, there is a decrease of 7% at a superplasticizer percentage of 0.5% compared to normal concrete but still within the planned quality of 30%. Meanwhile, at a percentage of 0.75%, a significant decrease in compressive strength by 28% was observed compared to normal concrete, with the compressive strength falling below the planned quality at 25.31 MPa.

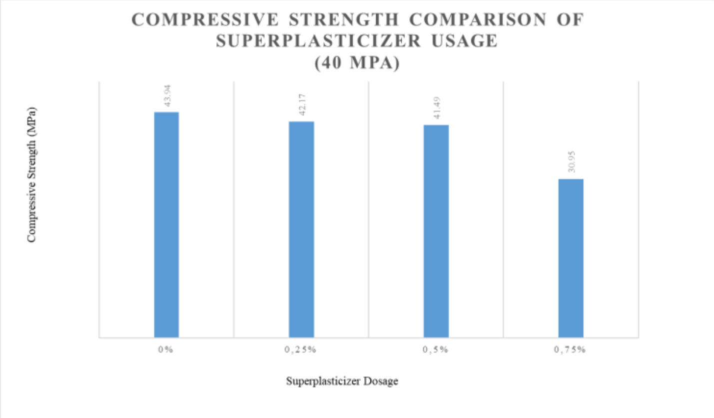

Figure 7. Compressive Strength of 40 MPa Concrete with Various Percentages of Superplasticizer

The test results for the planned 40 MPa quality in Figure 7 indicate a decrease with each addition of superplasticizer percentage. At a 0.25% addition, there is a 4% decrease, but the compressive strength still meets the planned requirements. Furthermore, with a 0.75% addition, there is a 6% decrease, and the results still meet the planned compressive strength. However, at a 0.75% percentage increase, a significant decrease of 30% in compressive strength is observed compared to normal concrete, and at this percentage, the compressive strength is measured at 30.95 MPa. Therefore, it can be concluded that the compressive strength is significantly below the planned 40 MPa.

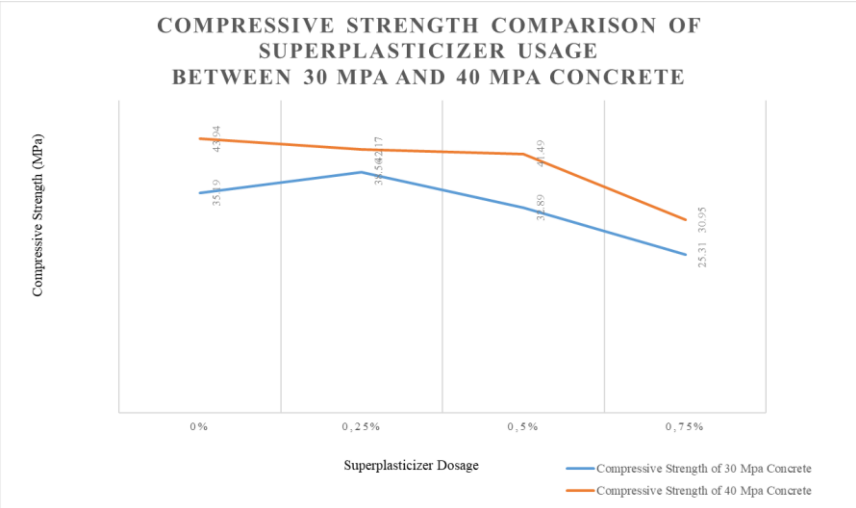

Figure 8. Comparison of Compressive Strength of 30 MPa and 40 MPa Concrete with Various Percentages of Superplasticizer

The effects of adding superplasticizer will be compared between two different planned strengths, namely 30 MPa and 40 MPa. Based on the results shown in Figure 8, it can be concluded that the addition of superplasticizer has different trends for the planned strengths of 30 MPa and 40 MPa. For 30 MPa strength, the optimum compressive strength is achieved at a superplasticizer addition percentage of 0.25%. On the other hand, for 40 MPa strength, the optimum result is obtained with normal concrete or 0% superplasticizer addition. Compared to the study [16], where the optimum compressive strength of 40 MPa was obtained at a superplasticizer percentage of 1.5%, an increase of 47.66% over the normal concrete compressive strength was observed. This is due to the use of a different type of superplasticizer.

CONCLUSION

According to the results of the research and data analysis on concrete testing with the addition of superplasticizer, several conclusions were drawn with respect to various research parameters, namely workability as observed from slump values and slump flow values, as well as the compressive strength of concrete. The following are some conclusions from this study:

1. Slump values meeting the standard specifications for variations in superplasticizer dosage indicate that the targeted compressive strength of 30 MPa is being considered, with a percentage addition of 0.5% and 0.75%, the values are 90 mm and 100 mm, respectively. Meanwhile, for the planned compressive strength of 40 MPa, with a 0.75% superplasticizer addition, the value is 75 mm. Thus, it can be concluded that the larger the percentage of superplasticizer addition, the greater the workability of the concrete.
2. In Self Compacting Concrete, the slump flow value is crucial to indicate that the concrete can be categorized as Self Compacting Concrete. In this study, it was found that the slump flow values with the addition of 0.5% and 0.75% superplasticizer already meet the criteria for Self Compacting Concrete, with slump flow test values exceeding 50 cm.
3. The optimum compressive strength value for the planned 30 MPa concrete is achieved with a 0.25% superplasticizer addition, resulting in a 10% increase in compressive strength compared to normal concrete. On the other hand, for the planned 40 MPa concrete, the optimum compressive strength is obtained with normal concrete, as each addition of superplasticizer leads to a decrease. The addition of 0.25%-0.5% superplasticizer in both planned strengths still yields compressive strength above the planned levels, despite the decrease. However, a 0.75% superplasticizer addition does not meet the planned compressive strength.

Based on the conclusions from the study, the addition of superplasticizer can enhance the workability of concrete but cannot optimally increase compressive strength.

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