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REVIEW OF THE EFFECT OF INDUSTRIAL WASTE ON SELF-COMPACTING CONCRETE

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Abstract
Self-Compacting Concrete (SCC) is an innovation in concrete technology used in building elements with dense and complex reinforcement frameworks. SCC is characterized by its high fluidity and the ability to self-compact without the use of vibrators. Superplasticizer is one of the components applied in the production of SCC. The use of superplasticizer aims to reduce water consumption, accelerate the setting time, improve concrete workability, and also make the concrete impermeable. As time progresses, industrial waste continues to increase, highlighting the importance of recycling industrial waste. The purpose of this research is to investigate the influence of industrial waste as a substitute material for fine aggregates on the workability and compressive strength of SCC. This study is the result of a literature review by examining various sources including books, proceedings, as well as international and national journals. The results of this literature study involve the use of industrial waste materials such as recycled glass, granite waste, nickel slag, and copper slag as substitutes for fine aggregates. The results of the workability and compressive strength of SCC are influenced by the characteristics of each industrial waste used. This indicates an improvement in the flowability (slump flow) with an increasing percentage of industrial waste, ranging from 0% to 60%, in the concrete composition. Compressive strength test results indicate that the optimal percentage of industrial waste addition in the concrete composition lies between 20% and 40%."

Keywords: self-compacting concrete, waste industrial, compressive strength, slump flow.

INTRODUCTION

Currently, technological developments in the concrete scope have experienced extraordinary rapid progress. This phenomenon has encouraged various research and experiments in the concrete field to improve its quality. The latest technology in terms of materials and implementation methods resulting from these experiments and studies aims to meet the increasing need for the use of concrete. Apart from that, this technology also aims to overcome various problems that often arise during the construction process in the field. In projects such as high-rise buildings and other complex structures constructions, easily-applied high-strength concrete is essential. Innovation is necessary to make concrete materials with natural flow capabilities without requiring compaction to face the challenges of casting in construction with a solid framework (Yanto Hermansah & Sihotang, 2019).

One solution to obtain a concrete mixture with superior density and durability is using the Self Compacting Concrete (SCC). Self

Compacting Concrete (SCC) is a type of concrete that has a high fluid level, allowing it to flow freely and fill every space in the mold without requiring a compaction process. One of the components involved in the production of SCC concrete is a superplasticizer as an additional material. Superplasticizer is a type of supplementary material that has chemical properties and is more commonly used to improve the performance of the implementation process (Poerwodihardjo & Sari, 2022)

Currently, one of the problems in the world is the large amount of by-products waste from industry. Due to limited land and increased costs for landfills, recycling or using industrial waste in concrete innovation can be one of the solutions, which will have a positive impact both environmentally and economically (Gupta & Siddique, 2019)

Based on the explanation above, this research was to look at the effect of industrial waste on self-compacting concrete.

LITERATURE REVIEW

Self Compacting Concrete (SCC) is one type of concrete with cohesive properties that can flow and become solid using its weight and can be worked out without bleeding or segregation in the concrete (Alwie et al., 2020). To produce natural compaction, Self-Compacting Concrete (SCC) is influenced not only by a high level of deformability but also by the ability of coarse aggregate and mortar to withstand when the concrete flows through the reinforcement (Okamura & Ozawa, 1996). Superplasticizer is used in making Self-Compacting Concrete (SCC) to produce a uniform distribution of cement particles. One potentially vital part of the SCC manufacturing process is the composition of both coarse and fine aggregate (Persson, 2001).

According to the European Federation Dedicated to Specialist Construction Chemicals and Concrete Systems (EFNARC), SCC concrete has the following characteristics:

1) Filling ability: the concrete's capability to automatically fill and flow to all places in the mold using its weight.
2) Passing ability: the ability of concrete to flow through the gaps between iron reinforcement or narrow gaps in the mold without segregation.
3) Segregation resistance: the ability of SCC concrete to maintain a uniform composition during the transportation process until casting.

This literature study will use industrial waste to replace fine aggregate material. This industrial waste is in the form of recycled glass, granite waste, nickel slag, and copper slag.

Glass is a type of waste material that requires recycling and can change into various forms (Sharifi et al., 2013). There are many ways of utilizing glass waste in the construction industry worldwide. One of them is the practical use of waste glass in structural concrete, especially SCC, which still has limitations until now. The chemical composition of the glass fragments is in Table 1.

Table 1 Chemical Composition of Glass Fragment

No	Element	Percentage
1	SiO_2	70.50
2	Al_2O_3	2.60
3	Fe_2O_3	-
4	CaO	5.70
5	MgO	2.90
6	SO_3	0.20
7	Na_2O	16.30
8	K_2O	1.20

(Source: Sharifi et al., 2013)

The impact of using granite powder waste on normal concrete's mechanical characteristics by changing up to 25% of the sand weight causes a decrease in the concrete's workability (Vijayalakshmi et al., 2013). The optimum level of granite waste substitute for compressive strength, split tensile strength, and flexural strength is at the level of 15%, with values tending to be comparable to or slightly lower than the control mixture. In the research (Jain et al., 2019), the granite waste used has a chemical composition as described in Table 2.

Table 2 Chemical Composition of Granite Waste

No	Element	Percentage
1	O	51.53
2	Si	24.34
3	Al	11.27
4	Na	3.93
5	C	2.27
6	K	1.23
7	Fe	2.99
8	Mg	0.91
9	Ca	0.53

(Source: Jain et al., 2019)

The concrete's workability increases along with the increase in the copper slag's percentage as a substitute for sand, and the compressive strength has increased to a substitution of 40-50% (Al-Jabri et al., 2011). In the research (Gupta & Siddique, 2019), the copper slag used in concrete has a chemical composition as described in Table 3.

Table 3 Chemical Composition of Copper Slag

No	Element	Percentage
1	SiO_2	33.62
2	Al_2O_3	3.65
3	FeO	55.60
4	CaO	3.31
5	MgO	1.51
6	SO_3	1.12
7	Na_2O	0.37
8	K_2O	0.82

(Source: Gupta & Siddique, 2019)

The addition of nickel slag as a substitute for fine aggregate increases bleeding in concrete, and the compressive strength increases with a substitution of 50% nickel slag (Saha & Sarker, 2017). In the research (Nuruzzaman et al., 2020), the nickel slag used has the following chemical compositions:

Table 4 Chemical Composition of Nickel Slag

No	Element	Percentage
1	SiO_2	51.93
2	Al_2O_3	2.92
3	Fe_2O_3	12.98
4	CaO	0.50
5	MgO	30.87
6	Others	0.80

(Source: Nuruzzaman et al., 2020)

METHOD

The research uses a literature study in the form of an analysis process involving collecting, evaluating, and synthesizing sources from scientific articles, books, journals, research reports, and other sources related to the use of industrial waste in SCC concrete. This method aims to understand developments in the reuse of industrial waste in concrete, which affect the workability and compressive strength of the concrete.

Based on the existing results, researchers conclude the influence of industrial waste on the workability and compressive strength of self-compacting concrete (SCC) concrete.

RESULTS/DISCUSSIONS

Composition of Self-Compacting Concrete

Variations of SCC concrete mixtures have been carried out in concrete innovations in each research to obtain high-quality SCC concrete. In this literature study, variations in concrete mixtures used industrial waste as a substitute for fine aggregate.

Previous research used various percentages of industrial waste. The following are several compositions in research that used industrial waste as fine aggregate.

Researcher	Type of Waste	Percentage of Substitute Materials
Sharifi et al.	Glass Fragment	0%, 10%, 20%, 30%, 40%, and 50%
Jain et al.	Granite Waste	0%, 20%, 40%, 60%, 80%, and 100%
Gupta & Siddique	Copper Slag	0%, 10%, 20%, 30%, 40%, 50%, and 60%
Nuruzzaman et al.	Nickel Slag	0%, 20%, 40%, and 60%

Effect of Industrial Waste on the Workability of SCC Concrete

Sharifi et al. stated that the ability of concrete to flow increases with increasing levels of glass fragments in the concrete composition. The resulting slump flow for all compositions has exceeded the minimum limit of 650 mm. This phenomenon is related to the low water absorption of the glass sand and the smooth surface, therefore providing a good indication of deformability. The slump flow results are in the figure below.

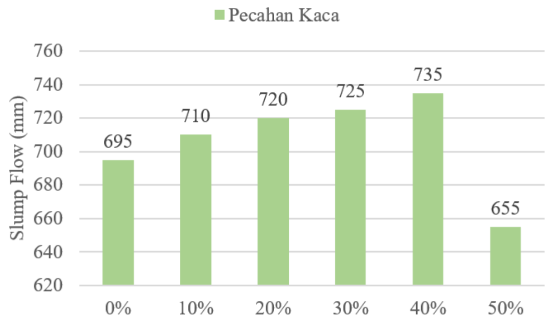

Figure 1 Slump Flow Results of Glass Fragment Substitution

Jain et al. stated that small granite waste aggregates are very influential in achieving the flowability of SCC concrete mixtures. In this research, slump flow results vary from 670 mm to 715 mm. The use of superplasticizer in this composition varies from 1.15% to 2.7% and has an optimum level of 1.15%. The following are the slump flow results for SCC concrete using granite waste as a substitute for sand.

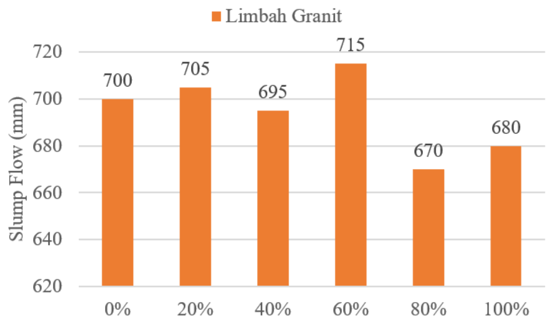

Figure 2 Slump Flow Results of Granite Waste Substitution

Gupta and Siddique stated that the slump flow value for a mixture of SCC with 100% sand was 685 mm. There is an increase in the slump value as the copper slag content increases in the mixture as fine aggregate from a variation of 0% to 60%. The rise in flowability is due to the fine aggregate texture and low water absorption of the slag granules. However, mixtures containing more than 40% copper slag experience signs of bleeding and segregation. The following are the slump flow results for SCC concrete using copper slag as a substitute for sand.

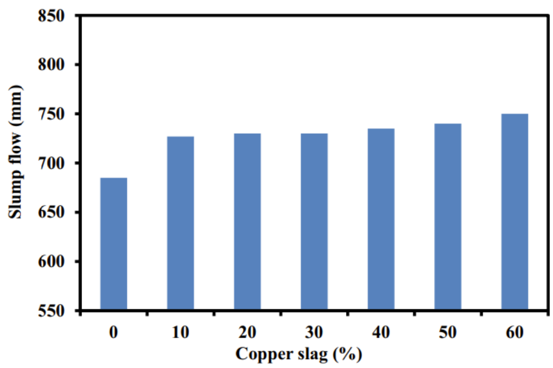

Figure 3 Slump Flow Results of Copper Slag Substitution

Sun et al. stated that the flowability of concrete decreased as the nickel slag content increased in the concrete mix. The decrease was due to the large size and shape of the nickel slag particles. The following are the slump flow results for SCC concrete using nickel slag as a substitute for sand.

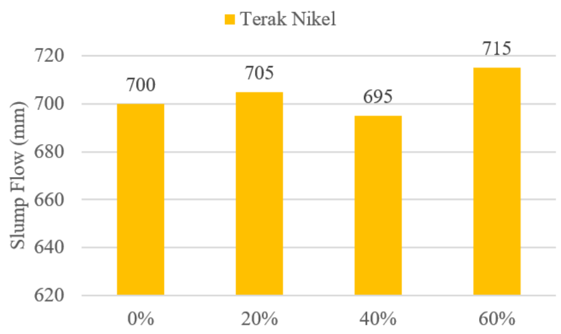

Figure 4 Slump Flow Results of Nickel Slag Substitution

The Effect of Industrial Waste on the Compressive Strength of SCC Concrete

Concrete mixtures that use glass fragments have a compressive strength value that is not much different from concrete without glass fragments. Replacing glass fragments with fine aggregate produces compressive strength results that are still reasonable in percentages below 50%. The addition of 50% glass fragments can reduce the compressive strength value by 8% compared to the normal mixture (Sharifi et al., 2013). The following are the results of the compressive strength of SCC concrete using glass fragments as a substitute for sand.

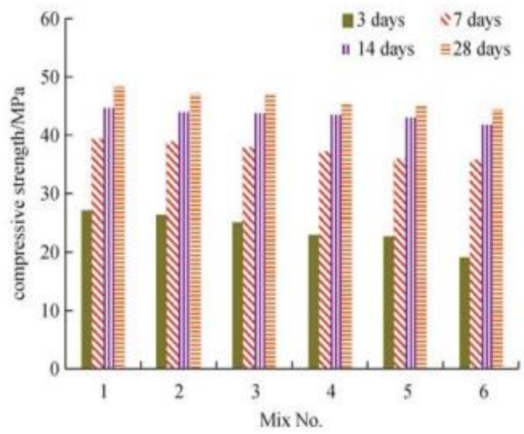

Figure 5 Results of Compressive Strength of Glass Fragment Substitution

In the research of Jain et al., Compressive strength tests were on the 7-day and 28-day concrete. On the 7-day concrete, the compressive strength ranges from 21.67 Mpa to 38.67 Mpa for all SCC concrete samples. Meanwhile, on 28-day concrete, the compressive strength value ranges from 31.50 MPa to 55.00 MPa for all SCC concrete samples. The following are the results of the compressive strength of SCC concrete using granite waste as a substitute for sand.

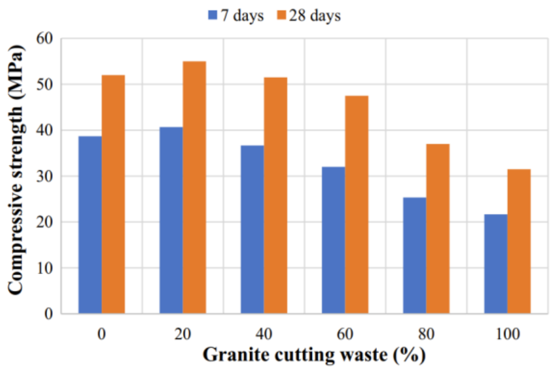

Figure 6 Compressive Strength Results of Granite Waste Substitution

In Gupta and Siddique's research, compressive strength tests were on 7-day, 28-day, and 90-day concretes. Concrete mixtures that use copper slag in the concrete composition have compressive strength values that are not much different from concrete mixtures that do not use copper slag (normal concrete). The optimum percentage level of copper slag in the concrete mixture for a compressive strength value that exceeds the control concrete is 30%. The following are the results of the compressive strength of SCC concrete using copper slag as a substitute for sand.

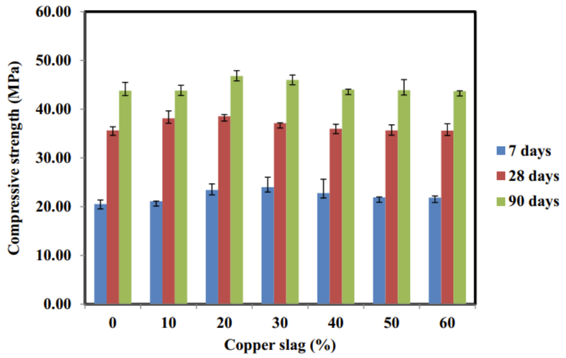

Figure 7 Compressive Strength Results of Copper Slag Substitution

In the research of Sun et al., Compressive strength tests were on 7-day and 28-day test objects. The 28-day test objects are distinguished between vibrated and non-vibrated concrete. The 7-day concrete that uses nickel slag in its composition experiences an increase in compressive strength values of 1%, 34%, and 31% for the FNS20, FNS40, and FNS60 mixtures. Meanwhile, the 28-day concrete using nickel slag in its composition experiences an increase in compressive strength values of 3%, 30%, and 22% for the FNS20, FNS40, and FNS60 mixtures. The following are the results of the compressive strength of SCC concrete using nickel slag as a substitute for sand.

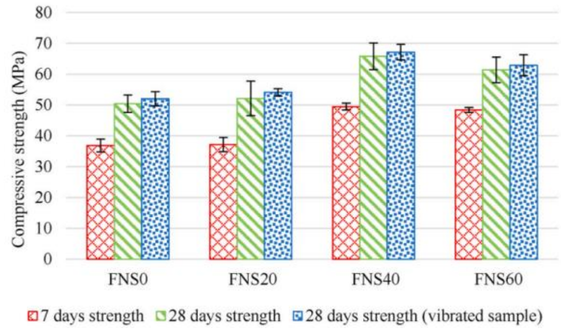

Figure 8 Results of Compressive Strength of Nickel Slag Substitution

CONCLUSIONS

From the explanation in the previous sub-chapter, the conclusions are:

1. The workability results of SCC concrete using industrial waste depend on the characteristic properties of the industrial waste. In general, industrial waste increases the flowability of SCC concrete as the industrial waste content increases by 0% to 60%.
2. The characteristics of industrial waste also influence the compressive strength results. The optimum percentage of glass fragment substitution concrete is 10%, granite waste substitution concrete is 20% and 40%, copper slag substitution concrete is 20% and 30%, and nickel slag substitution concrete is 40%.

It is better to expand the study on testing the characteristics of SCC concrete such as T50, V-funnel, L-box, or U-box to improve the quality of literature studies on SCC concrete. Many types of industrial waste can be used in SCC concrete.

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RESULTS/DISCUSSIONS

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Gupta & Siddique	Copper Slag	0%, 10%, 20%, 30%, 40%, 50%, and 60%
Nuruzzaman et al.	Nickel Slag	0%, 20%, 40%, and 60%

Effect of Industrial Waste on the Workability of SCC Concrete

Sharifi et al. stated that the ability of concrete to flow increases with increasing levels of glass fragments in the concrete composition. The resulting slump flow for all compositions has exceeded the minimum limit of 650 mm. This phenomenon is related to the low water absorption of the glass sand and the smooth surface, therefore providing a good indication of deformability. The slump flow results are in the figure below.

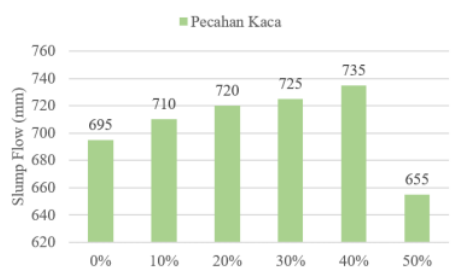

Figure 1 Slump Flow Results of Glass Fragment Substitution

Jain et al. stated that small granite waste aggregates are very influential in achieving the flowability of SCC concrete mixtures. In this research, slump flow results vary from 670 mm to 715 mm. The use of superplasticizer in this composition varies from 1.15% to 2.7% and has an optimum level of 1.15%. The following are the slump flow results for SCC concrete using granite waste as a substitute for sand.

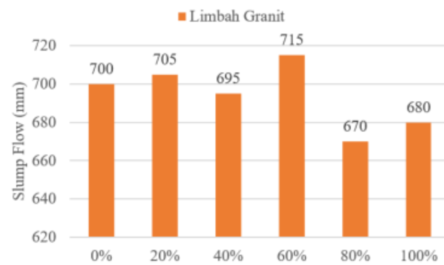

Figure 2 Slump Flow Results of Granite Waste Substitution

Gupta and Siddique stated that the slump flow value for a mixture of SCC with 100% sand was 685 mm. There is an increase in the slump value as the copper slag content increases in the mixture as fine aggregate from a variation of 0% to 60%. The rise in flowability is due to the fine aggregate texture and low water absorption of the slag granules. However, mixtures containing more than 40% copper slag experience signs of bleeding and segregation. The following are the slump flow results for SCC concrete using copper slag as a substitute for sand.

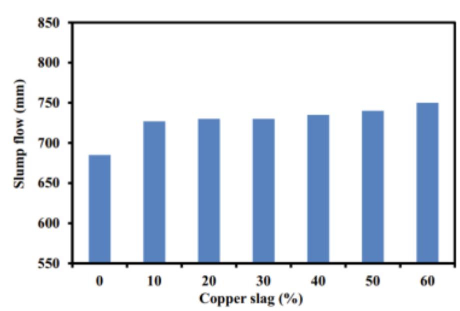

Figure 3 Slump Flow Results of Copper Slag Substitution

Sun et al. stated that the flowability of concrete decreased as the nickel slag content increased in the concrete mix. The decrease was due to the large size and shape of the nickel slag particles. The following are the slump flow results for SCC concrete using nickel slag as a substitute for sand.

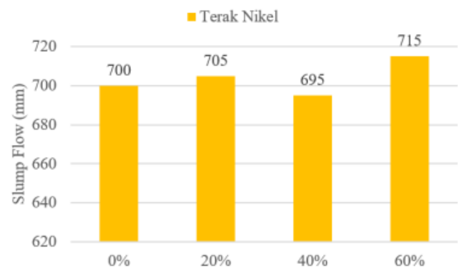

Figure 4 Slump Flow Results of Nickel Slag Substitution

The Effect of Industrial Waste on the Compressive Strength of SCC Concrete

Concrete mixtures that use glass fragments have a compressive strength value that is not much different from concrete without glass fragments. Replacing glass fragments with fine aggregate produces compressive strength results that are still reasonable in percentages below 50%. The addition of 50% glass fragments can reduce the compressive strength value by 8% compared to the normal mixture (Sharifi et al., 2013). The following are the results of the compressive strength of SCC concrete using glass fragments as a substitute for sand.

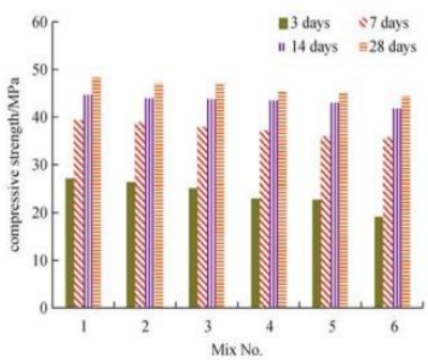

Figure 5 Results of Compressive Strength of Glass Fragment Substitution

In the research of Jain et al., Compressive strength tests were on the 7-day and 28-day concrete. On the 7-day concrete, the compressive strength ranges from 21.67 Mpa to 38.67 Mpa for all SCC concrete samples. Meanwhile, on 28-day concrete, the compressive strength value ranges from 31.50 MPa to 55.00 MPa for all SCC concrete samples. The following are the results of the compressive strength of SCC concrete using granite waste as a substitute for sand.

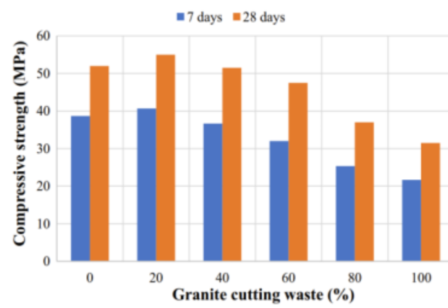

Figure 6 Compressive Strength Results of Granite Waste Substitution

In Gupta and Siddique's research, compressive strength tests were on 7-day, 28-day, and 90-day concretes. Concrete mixtures that use copper slag in the concrete composition have compressive strength values that are not much different from concrete mixtures that do not use copper slag (normal concrete). The optimum percentage level of copper slag in the concrete mixture for a compressive strength value that exceeds the control concrete is 30%. The following are the results of the compressive strength of SCC concrete using copper slag as a substitute for sand.

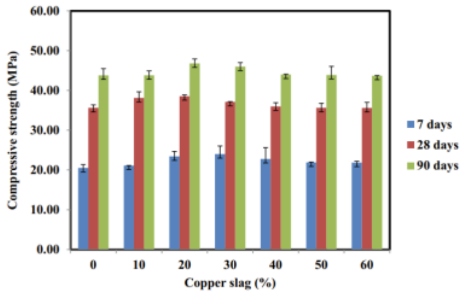

Figure 7 Compressive Strength Results of Copper Slag Substitution

In the research of Sun et al., Compressive strength tests were on 7-day and 28-day test objects. The 28-day test objects are distinguished between vibrated and non-vibrated concrete. The 7-day concrete that uses nickel slag in its composition experiences an increase in compressive strength values of 1%, 34%, and 31% for the FNS20, FNS40, and FNS60 mixtures. Meanwhile, the 28-day concrete using nickel slag in its composition experiences an increase in compressive strength values of 3%, 30%, and 22% for the FNS20, FNS40, and FNS60 mixtures. The following are the results of the compressive strength of SCC concrete using nickel slag as a substitute for sand.

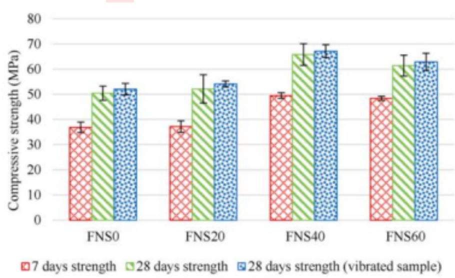

Figure 8 Results of Compressive Strength of Nickel Slag Substitution

CONCLUSIONS

From the explanation in the previous sub-chapter, the conclusions are:

1. The workability results of SCC concrete using industrial waste depend on the characteristic properties of the industrial waste. In general, industrial waste increases the flowability of SCC concrete as the industrial waste content increases by 0% to 60%.
2. The characteristics of industrial waste also influence the compressive strength results. The optimum percentage of glass fragment substitution concrete is 10%, granite waste substitution concrete is 20% and 40%, copper slag substitution concrete is 20% and 30%, and nickel slag substitution concrete is 40%.

It is better to expand the study on testing the characteristics of SCC concrete such as T50, V-funnel, L-box, or U-box to improve the quality of literature studies on SCC concrete. Many types of industrial waste can be used in SCC concrete.

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