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IOP Conference Series: Materials Science and Engineering

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To cite this article: Besty Afriandini *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **771** 012057

IOP Conf. Series: Materials Science and Engineering **771** (2020) 012057 doi:10.1088/1757-899X/771/1/012057

Fresh and Hardened Properties of Self Fiber Compacting Concrete (SFCC) Incorporated with Zeolite and Nylon

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Abstract. This study discusses the use of zeolite waste and nylon fiber which are used as added material in making concrete. The type of concrete used is self fiber compacting concrete (SFCC). Self-Compacting Concrete (SCC) is a type of concrete that emphasizes a high enough workability value so that the concrete can flow and solidify itself during the casting process. In this study, fresh and hardened properties will be tested. The fresh properties tested consisted of slump flow, T50, V-Funnel and L-Box while the hardened test of concrete consisted of compressive strength, splitting tensile strength and flexural strength. Nylon fiber is used as much as 1% of the weight of cement with length of 50 mm, while zeolite ash is used as a substitute for cement with variations of 5%, 10% and 15%. The purpose of this study was to determine the effect of nylon and zeolite ash variations on fresh and hardened properties of self fiber compacting concrete. The results show that using these two additional materials can be applied to self-compacting concrete because it meets predetermined standards for the fresh properties of concrete. In the hardened properties of the mixture of 5% zeolite produces higher compressive strength, splitting tensile strength and flexural strength than other variations. It can be concluded that the content of 1% fiber and 5% zeolite ash instead of cement is the optimum level and suitable for self-fiber compacting concrete.

1. Introduction

Self-compacting concrete is a type of concrete developed from conventional concrete to increase the value of its workability. Self-compacting concrete was first introduced in Japan in the mid-1980s to produce concrete with fairly good performance [1, 2]. Self-compacting concrete can be defined as a type of concrete that can flow and compact by itself due to gravity without the help of vibrators and workers, so this concrete requires a high level of fresh performance to avoid segregation [3, 4]. In its development, self-compacting concrete has been applied in various infrastructures in several countries [5], implementation of this type of concrete is also used for structural pre-stressed beam girder [6], Dams [7], and in buildings [8]. This concrete is used to facilitate its specific work in areas that are difficult to be compacted manually during the casting process.

Self-compacting concrete is very suitable for building structures that have a high level of difficulty, this type of concrete is very helpful in maintaining the quality of concrete to remain in accordance with standards and reduce the number of pores produced by concrete due to not being perfectly solid. In the manufacturing process, self-compacting concrete tends to require a fairly high number of binders, especially cement, so that a lot of research is done to reduce the amount of cement used but still produce

IOP Conf. Series: Materials Science and Engineering **771** (2020) 012057 doi:10.1088/1757-899X/771/1/012057

a pretty good performance. Previous researchers have used fly ash as a substitute for cement [9, 10], Palm oil ash waste ash [11, 12], baggase ash [13, 14], and also recycled concrete aggregates [15, 16]. Utilization of this waste is based on its chemical properties which contain pozzolan properties making it suitable to be used as a cement substitute partially.

The nature of concrete which has a high level of resistance to the compressive force, but is weak in holding the tensile force. If the tensile strain produced exceeds the tensile strain capacity, cracking in the concrete will occur. One method for increasing the tensile strength of concrete is to add fibrous material. Research on fiber concrete has been carried out such as by adding nylon to normal concrete [17, 18], Polypropylene fiber [19, 20], plastic waste and recycled fiber [21, 22], and with various other types of fibers both organic and inorganic fibers. While the use of fiber in self-compacting concrete has not been done much so it needs to be tested further on the effect of fiber on the workability value of self-compacting concrete.

In this study fresh and hardened properties will be tested on self-fiber compacting concrete with fiber composition of 1% to the weight of cement and added with zeolite variations of 5%, 10% and 15% as a substitute for cement. The purpose of this study is to determine the effect from fiber and zeolite as a substitute for cement to the characteristics of self-compacting concrete. Fresh properties testing is done to determine the ability of concrete in maintaining performance so that it can still be categorized as self-compacting concrete. The fresh properties testing is done in the form of slump flow, T50, V-Funnel and L-Box. Whereas the testing of hardened properties is carried out to determine the mechanical properties of concrete, the tests are in the form of compressive strength, spitting tensile strength and flexural strength. The testing period starts from 7, 14 and 28 days. Through this research it is hoped that it can improve the performance of self-fiber compacting concrete by utilizing waste materials so as to reduce the production price of concrete.

2. Experimental Program

2.1. Materials and Mix Design

In this study using materials composed of cement, water, fine aggregate, coarse aggregate, zeolite, superplasticizer and fiber. Before being used as a constituent, coarse and fine aggregates are first tested for properties as shown in Table 1. Tests are carried out in the form of examining specific gravity, moisture content, absorption, roughness values up to mud content. The test results of each aggregate indicate that this type of aggregate is suitable for use as a material making up concrete.

Table 1. Fines and coarse aggregate properties

Test Item	Unit	Fines Aggregate	Coarse Aggregate
Water Content	%	3.71	1.97
Specific Gravity	-	2.58	2.65
Absorption	%	0.82	0.75
Mass Density	gr/cm^3	1.53	1.55
Mud Content	%	4.01	0.91
Roughness content	%	-	32.87

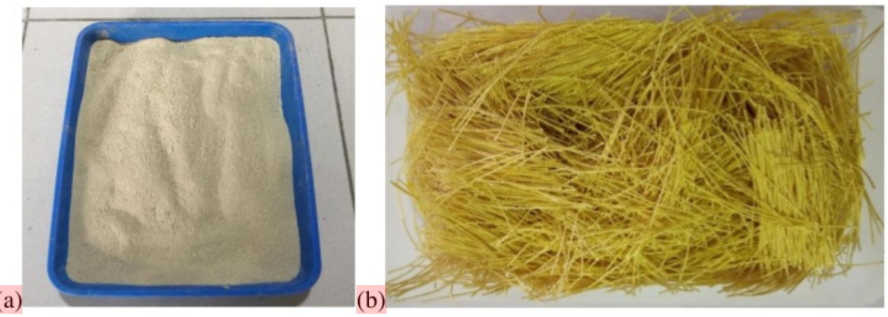
The use of cement in the manufacture of self-compacting concrete is generally required in high enough quantities so that it will increase the price of this type of concrete production. In addition, the large number of waste materials that have pozzolanic characteristics in Indonesia is certainly a good enough method to produce concrete that is both efficient and environmentally friendly. In this study using zeolite waste as a substitute for cement. The percentage used varies from 5%, 10% to 15% of the weight of normal cement used. In Table 2 a comparison of the chemical content in the zeolite ash used and the chemical content in cement. Table 2 shows that Portland cement has high CaO, SiO_2 and Al_2O_3 contents, as well as the results obtained by zeolite ash.

Table 2. Chemical Properties of Portland cement and Zeolite Ash [23]

Materials	SiO_2	K_2O	Fe_2O_3	CaO	MgO	Al_2O_3	Na_2O	SO_3
PC	18.68	0.73	3.53	64.56	0.98	4.67	0.14	3.00

ZA	68.85	2.19	1.29	3.97	1.06	11.71	0.29	0.18

One of the important constituents in this research is nylon fiber. Figure 1 (a) shows the shape of Zeolite ash, while Figure 1 (b) shows the shape of the nylon fiber used. Nylon fiber is a composite added material used to increase the tensile strength of concrete and flexural strength. The nylon fiber used in this study has a length of 50 mm aimed at controlling early cracking and increasing durability. Nylon fiber is used as much as 1% of the weight of cement.



(a) (b)

Figure 1. (a) Zeolite Ash; (b) Nylon fiber

In this study, using 4 variations of the mixture that there are differences in the content of zeolite as a substitute for cement. In Table 3 the mix design results for each variation used for 1m3. The mix design used in this study adopts Agrawal, et al in 2008 [24].

Table 3. Mix design for each variation in kg/m^3

Materials (Kg)	0% ZA	5% ZA	10% ZA	15% ZA
Cement	485.00	460.75	436.50	412.25
Zeolite Ash	0.00	24.25	48.50	72.75
Fines Aggregate	600	600	600	600
Coarse Aggregate	561	561	561	561
Superplasticizer	7.275	7.275	7.275	7.275
Nylon Fiber	0.00	4.85	4.85	4.85
Water	135	135	135	135

In this study, using the water to binder ratio with the same conditions for all variations so that it can be known whether the increasing amount of zeolite used will affect the workability of each mixture. The superplasticizer used in this study is a special SP for self-compacting concrete that is widely used in Indonesia, namely the Sikament NN type. The superlastisizer content used is 0.8% with the expectation that it can improve workability even though the water to binder ratio used is only 0.28.

2.2. Fresh Properties Test

Fresh properties testing conducted in this test consists of four parts, namely slump flow, T50, V-Funnel and L-Box. All testing criteria follow the standards set by the European Federation of National Trade Associations Representing Producers and Applicators of Specialist Building Products (EFNARC) [25]. In the testing of slump flow and T50 using the same equipment as shown in Figure 2 (a) where the purpose of this test aims to determine the ability of flow ability of fresh concrete mix. Whereas in Figure 2 (b) is a form of L-Box testing tool that aims to determine the ability of passing ability that is the ability to pass obstacles that have been provided in such a way according to established standards. V-funnel testing is carried out to determine the value of viscosity and filling ability using tools as shown in Figure 2 (c).

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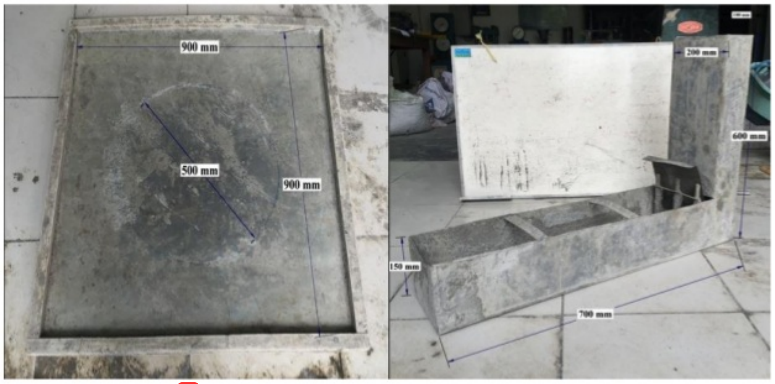

(a) (b)

(c)

Figure 2. Fresh properties check tools (a) Slump flow; (b) L-Box; (c) V-funnel

2.3. Hardened Properties Test

Tests carried out in the form of compressive strength, tensile strength and flexural strength in each test follow different standards. Each test is done at the age of 7, 14 and 28 days by curing using water curing. The compressive strength test uses dimensions of 150 mm diameter with 300 mm height [26], while the tensile strength test uses specimens with the same dimensions as the compressive strength, only my test position is different [27]. Flexural strength testing uses point loading in the middle of the test specimen with a 150x150x600 mm specimen size [28].

3. Result and Discussion

3.1. Fresh Properties

Fresh properties testing conducted in this study consisted of checking the slump flow, T50, V-Funnel and L-Box with the results that can be seen in Figure 3. In the slump test it was seen that overall it met the specified specifications. The results show that the higher the zeolite content in the concrete mixture the slump flow value will decrease so this causes the flow ability value of fresh concrete to be reduced. The higher levels of zeolite used cause more water is up so that the spread value in the concrete becomes smaller.

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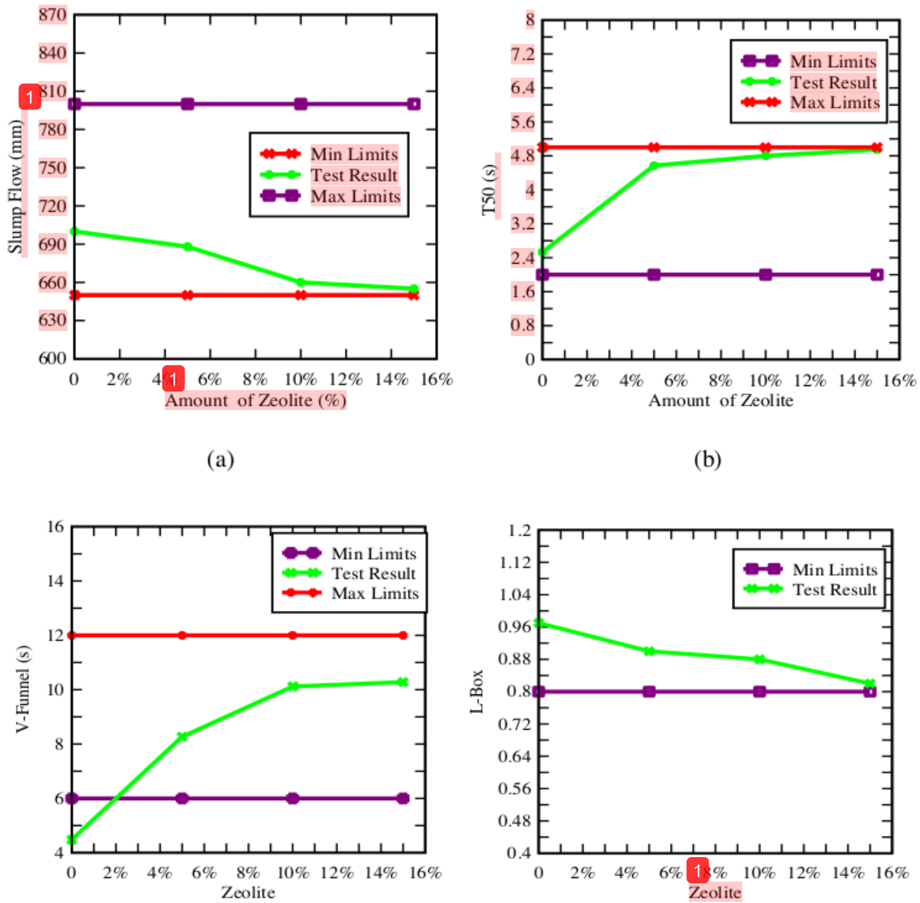

(c) (d)

Figure 3. Fresh properties result (a) Slump Flow; (b) T50; (c) V-Funnel; (d) L-Box

With the reduced value of the slump flow it will increase the T50 value because the thicker the concrete produced takes longer the concrete to spread during the slump flow test. The level of plasticity of fresh concrete is very decisive sooner or later the concrete has spread, in Figure 3 (c) is the result of V-Funnel test. In self-fiber compacting concrete without using zeolite added ingredients, it can be seen that fresh concrete does not meet the specified standards. However, concrete with the addition of zeolite shows an increase in value so that it becomes better and meets specified specifications.

The L-Box test shows that the resulting value decreases with increasing levels of zeolite which is used as an added ingredient in place of cement. Overall shows that the maximum level of zeolite that can be used as self-fiber compacting concrete is 15%, when using more than 15% it is very likely that fresh concrete does not meet the specifications specified for self-compacting concrete.

3.2. Hardened Properties

Concrete compressive strength test carried out at the age of 7, 14 and 28 days in Figure 4 is the result of the compressive strength relationship with curing time. Curing conducted in this study is water curing for all test specimens. In Figure 4 (a) explains that concrete with a percentage of 5% zeolite produces a higher compressive strength than normal concrete without cement replacement. In normal self-concrete, the compressive strength is 27.4 MPa when the concrete is 7 days, 29.2 MPa when the concrete is 14

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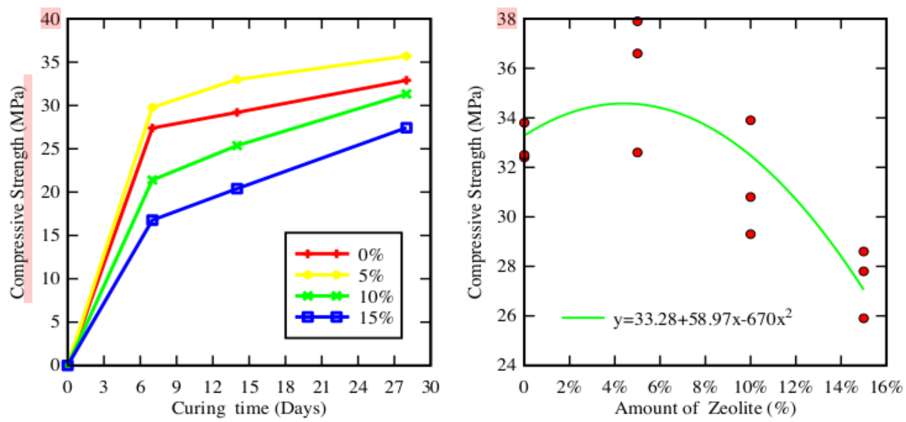
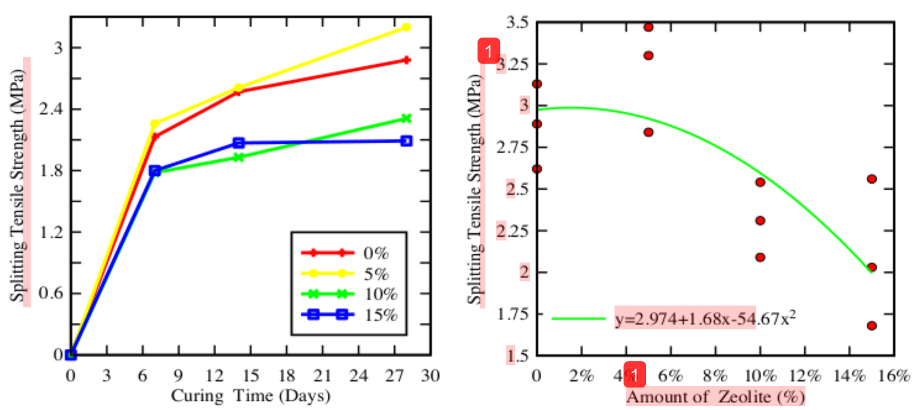
days and 32.9 MPa when the concrete is 28 days. Whereas concrete with 5% zeolite content produces compressive strength of 29.8 MPa when it is 7 days, 33 MPa when concrete is 14 days and 35.7 MPa for concrete with 28 days age. Concrete with variation of 10% and 15% zeolite produces a compressive strength that is smaller than normal concrete. Through this compressive strength results it can be concluded that the optimum optimal level in the use of zeolite in concrete is 5%.



(a) (b)

Figure 4. (a) Compressive strength; (b) relationship between compressive strength with amount of zeolite

Spitting tensile strength testing is done at the same age as compressive strength. The results of splitting tensile strength testing on self-fiber compacting concrete can be seen in Figure 5. The results show that 5% zeolite levels produce better tensile strength compared with 10% and 15% zeolite levels. This has similarities with the compressive strength described earlier. So it can be concluded that the tensile strength will produce optimum value when using zeolite levels of 5%. In Figure 5 (b) explains the relationship between splitting tensile strength and the amount of zeolite. The results show that there is an optimum level of cement replacement conditions as much as 5%, but as the amount of zeolite increases, the resulting tensile strength decreases.



(a) (b)

Figure 5. (a) Splitting tensile strength; (b) relationship between splitting tensile strength with amount of zeolite

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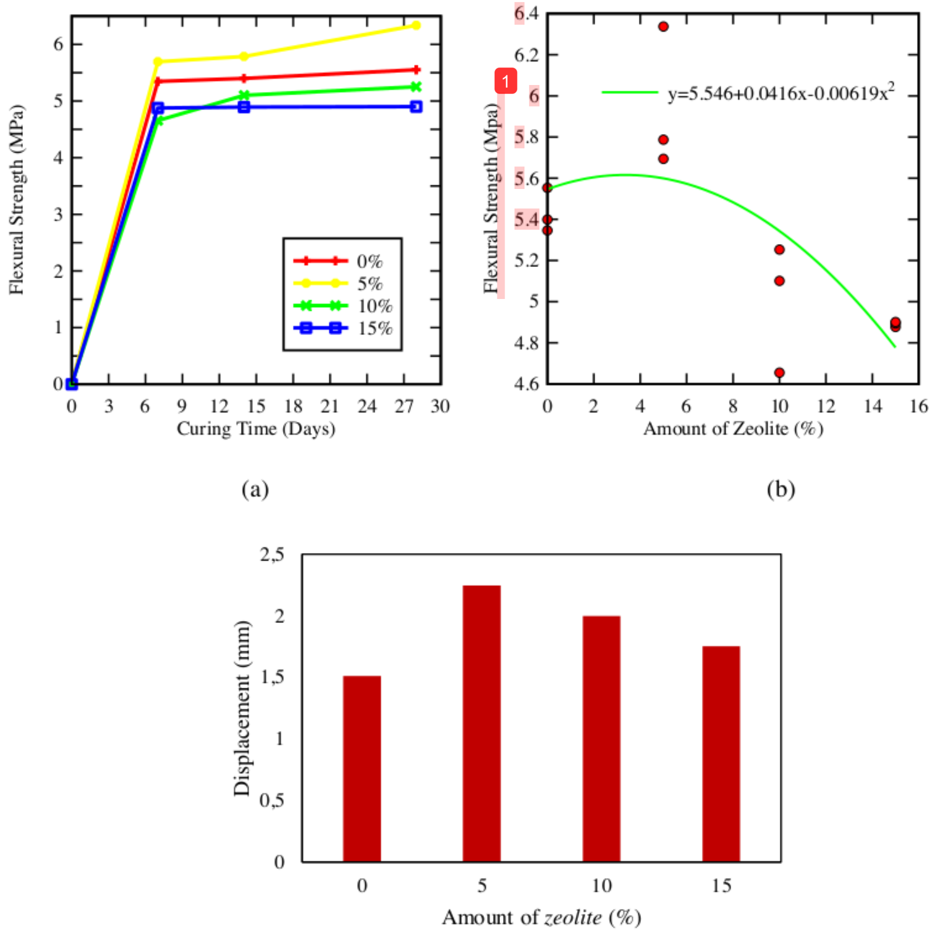
Flexural strength testing is performed at the age of 7, 14 and 28 days of concrete. The results showed that the flexural strength produced at 5% zeolite levels produced the highest value compared to the flexural strength in other variations. In Figure 6 shows the results of flexural strength testing and displacement generated in each mixture. In concrete using 5% zeolite, the displacement value is greater, this also corresponds to the value of the flexural strength produced. Meanwhile, with the increase in the amount of zeolite used, the resulting displacement value decreases, but the smallest displacement value is produced on the test object without using zeolite added ingredients. Overall on the hardened properties test it can be concluded that the 5% zeolite content is optimum for cement substitute added ingredients.



(a) (b)

(c)

Figure 6. (a) Flexural strength; (b) relationship between flexural strength with amount of zeolite; (c) maximum displacement from flexural strength

4. Conclusion

Based on the results and discussion can be summarized as follows:

1. Fresh properties test results show that the increasing value of zeolite added ingredients instead of cement will reduce the workability value. The 15% mixture level is the maximum level that can be used so that it meets the fresh properties requirements required by the standard.

2. The results of hardened properties show that 5% zeolite levels produce higher compressive strength, splitting tensile strength and flexural strength than in other mixes. So it can be concluded that the optimum level of zeolite is 5%.

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