IMPACT RESISTANCE OF HIGH STRRENGTH SELF COMPACTING CONCRETE WITH STEEL FIBER

Gabriella Agnes Luvena S.[1], M. Fauzie Siswanto[2], Ashar Saputra[3]

[1, 2, 3]Department of Civil and Environmental Engineering, Gadjah Mada University, Jl. Grafika No. 2, Yogyakarta, Indonesia
agnesluvena17@gmail.com[1]

ABSTRACT

The infrastructure needs like long-span bridge and tunnel in Indonesia has increased. Problems often arise in both these structures is the difficulty in casting and brittle nature of concrete caused the cracks. Thus, research is needed on the addition of fibers in concrete to obtain concrete with better durability and simplify the implementation. This study aimed to determine the effect of steel fibers on the physical and mechanical properties of *self-compacting concrete* (SSC) with a high quality with a target of about f_c'= 70 MPa.

This study usesbrand steel fibers *Dramix* a 3Dto the specifications of *tensile*strength: *Rm*,nom:1,225 N / mm^2, *tolerances:*± 7.5% avg, *Young's*Modulus:± 210 000 N / mm^2.Steel fiber diameter of 0.75 mm, an aspect ratio of length to diameter (l / d) 80 and the variation of the volume fraction of 0%, 0.5%, 0.75% and 1%. The physical properties of fresh concrete in this study were tested with a *slump*flow, *V-funnel*and *L-box.*Mechanical properties will be reviewed shock resistance of concrete at the age of 7, 14 and 28 days. Testing concrete shock resistance using a standard ACI *Committee* 544.

These results indicate that elevated levels of steel fibers will decrease the *workability* of the fresh concrete of high quality SCC. The physical properties of fresh concrete with the addition of fiber 0.5% and 0.75% eligible according to *the European Guidelines For Self Compacting Concrete* (TEGFSCC-2005) but with the addition of fiber SCC 1% are not eligible. The addition of up to 1% fibers improve the mechanical properties of high quality SCC concrete. The results of testing the average age of 28 days for shock resistance in SCC with a fiber content of 0%, 0.5%, 0.75% and 1% is 9, 23.67, 25, and 27 blows to the total collapse of concrete. Based on these results, it is recommended the use of the fiber of 0.75% of the volume of concrete because it can improve the mechanical properties of concrete and cater for all the requirements of s*elf compacting*concrete.

Keywords: Self compacting concrete, steel fiber, high strength concrete

A. INTRODUCTION

Background

The need for a high building infrastructure because the land is limited, long-span bridges, aqueducts, roads, and tunnels for the MRT, as well as a dam or levee to prevent flooding is increasing. Such buildings require quality better building materials that are safe, comfortable, and durable. One of the innovations that can be used is a high quality concrete. According to ISO-PD-T-04-2004-C high quality concrete is concrete with compressive strength required f_c’ 40 MPa - 80 MPa. High strength concrete has durability and a higher density than normal concrete. Concrete strength is influenced by the value of the water-cement ratio

(*w/c*). Low water-cement ratio will have a high compressive strength but will reduce *workability* of concrete.

The use of high strength concrete that has low *w/c*this would cause difficulties during consolidation especially structures that have small dimensions and reinforcement complicated. *Self-compacting concrete* (SCC) can be a solution to this problem. SCC is a concrete which can be solidified by itself without the aid of a vibrator. SCC will be filled and packed all parts in the mold although it is complicated or small dimensions without the need compactor.

Problems related to the durability of the nature brittle and easily cracked concrete. Concrete cracks can occur in the early days of hardening or cracks that arise because of the work load. Brittle nature of concrete can be reduced by adding fiber to the fresh concrete mixture with materials that are more ductile and has a high tensile strength.

The tunnels in Europe already in use fiber-reinforced concrete as a solution to reduce the cracks that occur mainly at the tip or edge of concrete components. Research on fiber-reinforced concrete in Indonesia have also been developed.

This type of fiber that can be used in fiber-reinforced concrete which include natural fibers like-fibers or coconut fibers and man-made fibers such as *polypropylene,polyetilene,*or steel. According Tjokrodimulyo (2007), the addition of fibers into the concrete intended to add tensile strength, ductility, and resistance to cracking.

Thus, it is necessary to do research on the effect of the addition of steel fibers in *self-compacting concrete* of high quality. This study is expected to provide solutions and alternatives to address the needs and problems in the construction field, especially in Indonesia. This study aim to knowing the influence of steel fibers on the physical properties and impact resistance of high strength *self- compactingconcrete* high strength

B. LITERATURE STUDY

Rao (2010) a study of the use of steel fibers with the addition of fly ash class F. purpose of this study to determine the effect of replacement of cement with fly ash on the properties of fresh concrete and hard concrete using steel fibers. This study uses fly ash by 35% for all variations. Aspect ratio used by 15, 25 and 35 and the volume fraction of steel fiber of 0.5%, 1% and 1.5%. The test results on the fresh concrete showed no lower than the EFNARC SCC requirement, but all the concrete mix has a good flow ability as SCC. Strength and ductility of SCC concrete with fibers increased in volume fraction of 1% for an aspect ratio of 15, 25, and 35. The volume fraction (V) and aspect ratio (A) optimal at 1% and 25. The results show the influence of fly ash is not too looks at early concrete age, but the age of the concrete after 56 days, the effect is particularly evident in the fly ash concrete strength.

Vasusmitha and Rao (2013) examined the strength and durability of self-compacting concrete high qualityto improve the quality of SCC. Mix design of this research is based on thetrialmix. Value water/binderratio (*w/b*) used by 0.251. Testing fresh concrete used was a slumpflow,T_{50cm} slumpflow,V-funnel,T_{5min}V-funnel,and L-box.The test results of fresh concrete qualify as SCC according EFNARC. Testing fresh concrete in this study is the concrete compressive strength, split tensile strength, flexural strength, permeability and durability of high quality SCC at 28, 56, 90, and 180 days. The results of compressive strength, split tensile strength, and flexural strength SCC increases with increasing age of concrete. The results of *Chloride*'s permeabilityin high quality SCC showed a very low.

Reddy and Pawade (2012) investigated the influence of a combination of silica fume and steel fibers on the mechanical properties of the concrete class standards and linkages. The planned concrete grade M35 with (*w/c*) is 0.41. Variations silica fume used 0%, 4%, 8%, and 12% with steel fiber content of 0%, 0.5%, 1%, and 1.5% of the volume of concrete. These results indicate that the concrete compressive strength increases with increasing substitution of silica fume addition of steel fiber. The flexural strength of concrete has increased significantly in substitution of silica fume, 8%either with or without fiber.

AL-Ameeri (2013) investigated the influence of steel fibers on the mechanical properties of self-compacting concrete to reduce the brittle nature and the weak tensile strength of concrete. This study usesadded material superplasticizer Glenium51 and filler lime stonepowder. water/ cement ratio of 0.49 and water / powder ratio (*w/p*) of 0.32. Variations of the fiber in this study of 0.5%, 0.75%, 1%, 1.25%, 1.5%. The test results on the fresh SCC decreased with increasing the amount of fiber. The test results of concrete strength and modulus of elasticity increased in the early life of concrete by increasing fiber content, while at the age of 90 days, the rise was not too big. Results of testing the tensile strength and flexural strength sides in the SCC with steel fibers showed an increase compared to SCC without fiber. The test results UPV decreased with the increased amount of steel fibers.

Sharma, et al (2016) studied the behavior of compression member of self-compacting concrete with and without steel fibers. The purpose of this study was to obtain concrete with high durability. This study uses material added superplasticizer Glenium B233 and filler ultrafine calcium carbonate with steel fibers. “Dramix glued steel fibre” were used. The steel fibre content was varied as 0%, 0.5%, 0.75%, 1% and 1.5% by weight of cement. Results of testing concrete compressive strength increases with an increase in fiber to fiber content of 1%, and then decreased. The maximum increase in the compressive strength of concrete by 66% at 28 days and 50% at 60 days. The addition of steel fiber adds energy absorption ratio of 1.5 to 2.6 times and increase ductility ratio of concrete.

Murali, et al. (2014) studied the impact resistance and strength reliability of fiber-reinforced concrete using a two-parameter Weibull distribution. Procedure for impact resistance testing used ACI *Committee* 544. Steel fibers are used diameter of 1 mm and a length of 50 mm with a variation of 0.5%, 1% and 1.5%. Water-cement ratio is used of 0.42. Variations in test results were analyzed by using two-parameter Weibull distribution. The results showed the use of fibers in concrete increases impact resistance, changing patterns of nature brittle failure becomes ductile.

Haryanto (2006) research about impact resistance of lightweight alumunium fiberreinforced concrete with aggregate alwa.This research was aimed to know the addition of alumunium fiber influence to the impactresistance of lightweight concrete. In this research, lightweight concrete was made fromcement, water, sand, ALWA (Artificial Lightweight Aggregate) and Superplasticizer, mix designmethod was Dreux-Corrise Method. The specimen was plate with 20 cm diameter and 4 cmhigh. Variation of alumunium fiber addition was 0%, 0,35%, 0,75% and 1% cement weight. Thetest was done after 28 days age of specimen used drop weight machine.The results showed that the impact resistance of the concrete increase by the increase of the fiber until 0,75% and then decrease.

C. METHODOLOGY

This study uses the brandsteel fibers Dramix with a diameter of 0.75 mm, an aspect ratio of length to diameter (l / d) of 80, and the volume fraction of 0%, 0.5%, 0.75% and 1%.fiber specifications Dramix include tensilestrength:$R_{m,}$nom:1.225 N / mm^2, tolerances:± 7.5% avg, Young'sModulus:± 210 000 N / mm$^{2.}$Mechanical properties in terms of resistance to shock is high quality SCC at the age of 7, 14 and 28 days, The number of specimens used as many as 36 cubes. Impact resistance testis using a standard ACI Committee 544, the tool used is a machinedrop weight test with a14.2 kg weight and height fell 0.345 m.

Mix design in this study using a process of trial mix due to the high quality SCC is still no special procedures or rules. This study sets the w/c 0.25 for f_c'= 70 MPa. Silica fume as filler is used by 10% of the weight of the cement which refers to the research results Pujianto (2010). Superplasticizer as an addictive substance to maintain the workability of SCC use of SIKA products are Viscocrete-1003.Viscocrete-1003used in this study was set at 1% through the test results. Comparison of coarse and fine aggregate used 48% and 52% were obtained from analysis of test results gradation and fine grain modulus (MHB) mixture. Used fiber content of 0%, 0.5%, 0.75%, 1% refers to the study Rao (2010) and Pawade (2012).

Table 1. Material requirement for 1 m^3 high quality SCC with a fiber content of 0%, 0.5%, 0.75% and 1%

Volume Fraction	Cement (kg)	Sand (kg)	Split (kg)	Water (kg)	Silica fume (kg)	Viscocrete-1003 (kg)	Steel fiber (kg)
0.00%	511.3 245.8	472		983.45	98.35	9.83	0
0.50%	983.45	472	245.8	511.3	98.35	9.83	39
0.75%	511.3 245.8	472		983.45	98.35	9.83	58.5
1.00%	983.45	472	511.3	245.8	98.35	9.83	78

(Source: author)

Table 2. Specimen for impact resistance test

Age (days)	Volume fraction	Specimen
7	0.00%	3
7	0.50%	3
7	0.75%	3
7	1.00%	3
14	0.00%	3
14	0.50%	3
14	0.75%	3
14	1.00%	3
28	0.00%	3
28	0.50%	3
28	0.75%	3
28	1.00%	3
Total		36

(Source: author)

D. RESULTS AND DISCUSSION

Fresh concrete

Fresh concrete test results are in did include Slump-flowtest,V-funnel test,andL-Box test.Fresh concrete testing results are shown in Table 3and Figure 1-Figure 2. The standards used for testing of fresh concrete is EFNARC 2002 and TEGFSCC-2005.

a. Slump-Flow Test

The effect of the addition of fiber to the diameter of the slump-flow can be seen in Figure 1. The diameter of the spread of this SCC fresh concrete on steel fiber content of 0% slightly exceeds the requirements mentioned in the TEGFSCC-2005, while the SCC with the addition of fiber 0.5% - 1% qualified SCC class SF1 (for casting piles and some deep foundations) and SF2 (for casting walls, beams, floors, and columns). The measurement resultsdiameter Slump-flow tends to decrease with increasing fiber content in the concrete. This is due to the steel fibers are interconnected, and reducing workability of fresh concrete.

Table 3. Results of the test of fresh concrete

Code	Fraction volume	Slump Flow (mm)	V-*Funnel* (s)	L-Box
SCC	0%	870	7	0.87
BF 0.5%	0,50%	640	16	0.88
BF 0.75 %	1%	686	15	0.81
BF 1%	1,00%	600	-	0.70

(Source: author)

Keterangan:
SCC = SCC without fiber
BF 0.5% F = SCC with 0.5% fiber
BF 0.75%F = SCC with 0.75% fiber
BF 1%F = SCC with 1% fiber

b. Test V-Funnel

V-testfunnel aims to determine the ability of fresh concrete to fill the space by the time required to test fresh concrete to flow through the V-funnel. The test results of V-funnel test can be seen in Figure 2. The test resultsV-funnel showed that thetest object included in class VS1 / VF1 at SCC without fiber, while the SCC with fibers in a class VS2 / VF2. The effect of adding fiber to the SCC slowing the ability of fresh concrete to fill the space. SCC with 1% fibers content didn't qualifyV-funnel because of a blocking by steel fibers so that fresh concrete can not pass the V- funnel.

c. L-Box Test

L-box test aims to determine the passing ability of SCC. L-box test results can be seen in Figure 3. According EFNARC (2002), the value of h2 / h1 on L-box is between 0.8-1. In this study, the SCC with a fiber content of 0% to 0.75% still qualify passingability,whereas in the SCC with the addition of 1% of the fibers is not eligible. Increasing the amount of fiber in the SCC tends to reduce the ability of passing ability of SCC.

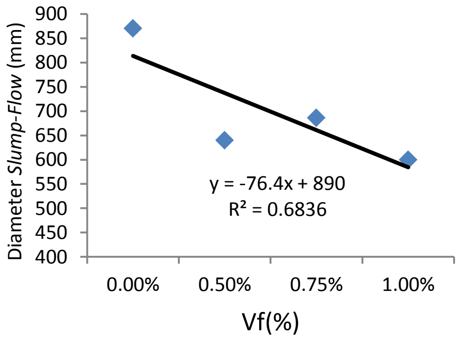

Figure 1. the test results *Slump-Flow* is based on the fiber content
(Source: author)

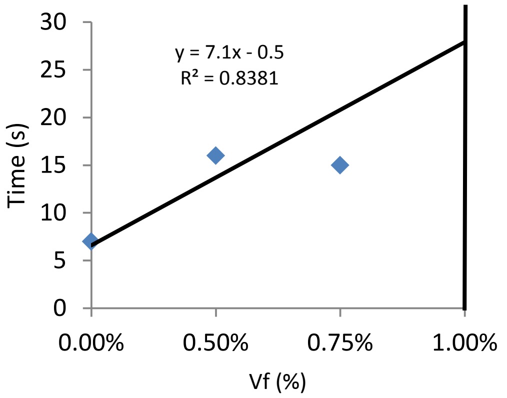

Figure 2. The test results V-*Funnel* based on the fiber content
(Source: author)

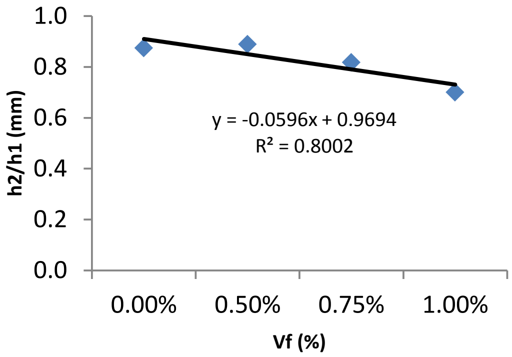

Figure 3. The graph of test results L-*Box* is based on the fiber content
(Source: author)

Impact Resistance Test

Test specimens for this test is a cube concrete with the size of 75x75x75 mm. The test data obtained from the number of blows required to total collapse concrete. Analysis of energy absorption calculated based on the number of blows it takes to make atotal collapse of the test specimen. The test results can be seen in Table 4,Figure 4andFigure 5.

Table 4. Test results of impact resistance test

Age (days)	Average of blows			
	ISCC	IF 0,5%	IF 0,75%	IF 1%
	0%	0,50%	0,75%	1,00%
7	7,33	20,33	24,00	19,00
14	6,67	15,00	16,67	19,33
28	9,00	23,67	25,00	27,00

(Source: author)

Description:
ISCC = SCC without the addition of fiber to testing impact
IF 0.5% = SCC with the addition of fiber by 0.5% for impact test
IF 0.75% = SCC with the addition of fiber by 0 , 75% for testing the impact
IF 1% = SCC with the addition of fiber by 1% for the testing of impact

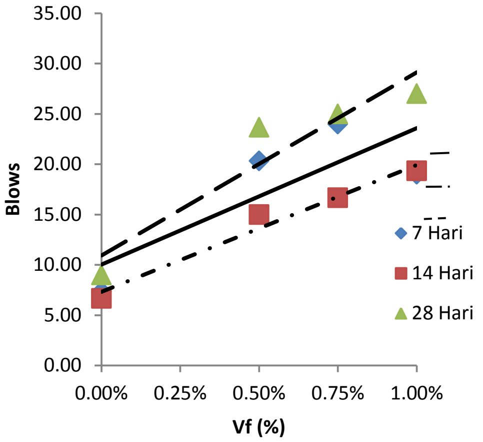

Figure 4. Graph of relations *impact* resistance of concrete with fiber content
(Source: author)

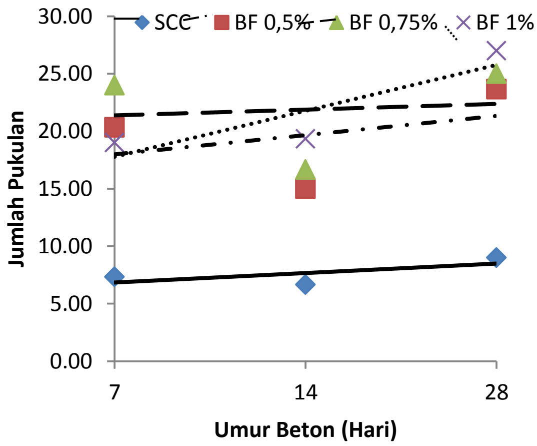

Figure 5. Graph relation *impact* resistance of concrete with age concrete

(Source: author)

Concrete with a high compressive strength will have higher impact resistance (Neville, 1987). The result of impact resistance test showedthe effect of fibers in concrete that increase the hardness and ductility of concrete. Concrete with fibers have a higher impact resistance rather than concrete without fiber. Energy absorption was calculated based on the number of blows it takes to make a total collapse of the test specimen. Steel fibers will begin to contribute after the first cracks to prevent the spread of crack and give additional strength to withstand the load. By the time the cracked concrete, fiber tensile strength will be tightened*(*fiberbridging*)*,then these fibers will absorb the energy caused by the load so that it has a better impact resistance than concrete without fiber. Steel fibers have high ductility so as to improve the ductility of fiber-reinforced concrete.
Impact resistance of concrete tends to increase with increasing age of the concrete for the hydration process in concrete. Values of impact resistance at 14 days decreased due to uneven fiber distribution for the specimen at the age of 7, 14, and 28 days. The amount of steel fibers less in the concrete reduces the effect on fiber-reinforced concrete. Figure 6 shows the test specimens after shock test (a) and shows that the distribution of fibers in the test object uneven cube (b).

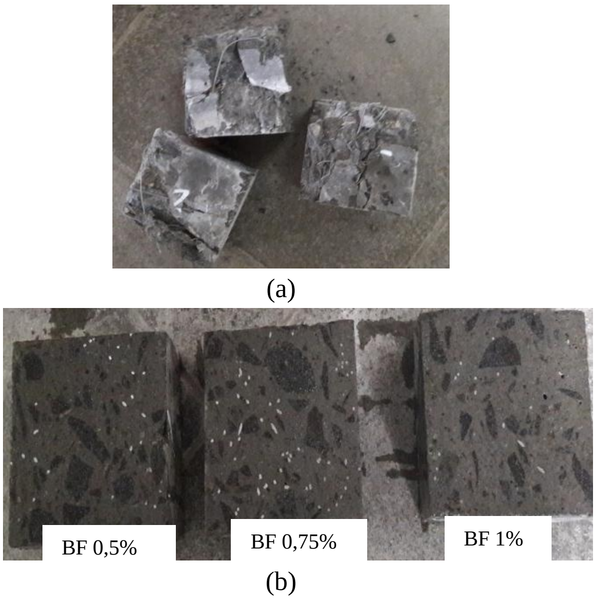

Figure 6. (a) The test specimen shock resistance testing of concrete (b) the distribution of the fibers in the test specimen shock resistance testing of concrete
(Source: author)

Figure 7 shows a comparison of the results with the research study Murali, et al. (2014) using afiber *hooked-end* with a length of 50 mm and an aspect ratio of 50. The results of this study impact resistance and research Murali, et al. (2014) have the same tendency is increased to the addition of 1% fiber. Improved shock resistance of this study reached 200% while research Murali, et al. reached 238%. Distribution and fiber orientation within each specimen will be very influential on concrete resistance against shock. It is affecting the increase in research Murali higher than these results despite lower compressive strength.

Research Haryanto (2006) about the impact resistance test in lightweight concrete with fibers showed an increase of energy absorption to the fiber content of 0.75% and a decrease in fiber content of 1%, whereas in this study is still increasing. This indicates that a high quality concrete has better resistance to shock with the addition of fiber to 1%.

The use of fibers in concrete will increase the amount of air in the concrete. This can decrease the strength and resistance to shock of concrete.

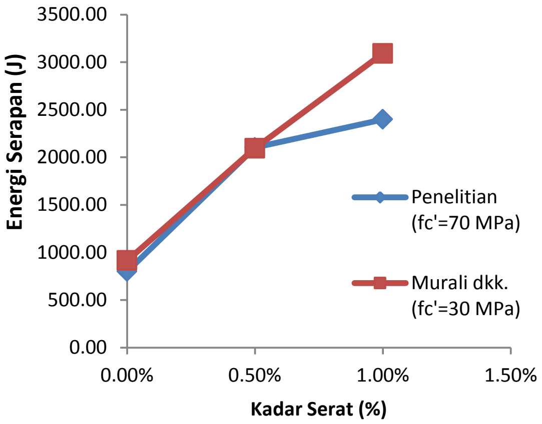

Figure 7. Graph fiber content relationship with the absorption energy research with previous research (Source: author)

E. CONCLUSION

Based on the results of research and discussion that has been described previously can be obtained several conclusions as follows.

1. steel fiber Dramix influence on self-compacting concrete of high quality. The addition of steel fiber Dramix lowering the workability of high strength self-compactingconcrete.The results of testing the workability of the slump flow qualified in the European Guidelines for Self-Compacting Concrete (TEGFSCC-2005) in the class SF1 and SF 2.
2. The test resultswith theV-funnel obtainedflow time of fresh concrete increases with increasing the amount of fiber. Time flow qualified in the European Guidelines for Self-Compacting Concrete (TEGFSCC-2005) for the SCC with the addition of fiber 0%, 0.5% and 0.75%, while the SCC with the addition of 1% fiber, fresh concrete can not be flows due to a clot that can not pass through the funnel V-funnel.
3. Results of testing withL-Box qualify for The European Guidelines for Self-Compacting Concrete (TEGFSCC-2005) for the SCC with the addition of fibers 0%, 0.5% and 0.75%, while the SCC with the addition of fiber 1% , fresh concrete can not flow through the holeL-Box.
4. The addition of steel fiber Dramix improve the mechanical properties of high quality SCC concrete. Resistance to shock the SCC has increased by 200% in the SCC with the addition of 1% fiber by the number of punches 27 times.

From the research that has been carried out, can be given advice that is expected to benefit, among others, are as follows.

1. Need to do further research using other added ingredients such as fly ash, the type of superplasticizer, and other fiber types.
2. The scope of the research conducted only includes physical and mechanical properties of SCC, still needs further research on the use of high strength SCC with fibers in structural beams or columns.
3. However, further research is needed for the mechanical properties of high strength SCC with fibers such as water absorption and durability.
4. Please note when printing fresh concrete so as to get a uniform concrete specimen.

ACKNOWLEDGMENT

The Author would like to thank you to PT. Findotek for providing Dramix steel fiber and the Gadjah Mada University for the laboratory.

REFERENCES

AL-Ameeri, A., (2013). The Effect Of Steel Fiber On Some Mechanical Properties Of Self Compacting Concrete. *American Journal of Civil Engineering*.

Ervianto, M., Saleh, F. & Prayuda, H., (2016). Kuat Tekan Mutu Tinggi Menggunakan Bahan Tambah Abu Terbang (Fly Ash) dan Zat Aditif (Bestmittel). *SINERGI*, XX, pp.199-206.

Haryanto, Y., (2006). *Kajian Ketahanan Kejut Beton Ringan Serat Alumunium Dengan Agregat Alwa. Dinarek, II.*

Liu, T.C. & Donald, J.E.M., (1981). *Abrasion-Erosion Resistance of Fiber-Reinforced Concrete*. Washington, D.C.

Miranty, R., (2014). *Pengaruh Pengunaan Silica Fume, Fly Ash, dan Superplasticizer pada Beton Mutu Tinggi Memadat Sendiri*. Yogyakarta: Universitas Atma Jaya Yogyakarta

Murali, G., Santhi, A.S. & Ganesh, G.M., (2014). Impact Resistance And Strength Reliability Of Fiber Reinforced Concrete Using Two Parameter Weibull Distribution. ARPN *Journal of Engineering and Applied Sciences*, IX.

Pujianto, A., (2011). *Beton Mutu Tinggi dengan Admixture Superplastisizer dan Aditif Silicafume. XIV*.

Rao, B.K. & Ravindra, P.V., (2010). Steel Fiber Reinforced Self Compacting Concrete Incoporating Class F Fly Ash. *International Journal of Engineering Science and Technology*.

Reddy, D.V. & Y.Pawade, P., (2012). Combine Of Silica Fume and Steel Fibre On Mechanical Properties On Standard Grade Of Concrete and Their Interrelations. *International Journal of Advanced Engineering Technology*, III(1).

sharma, S., sharma, V.K. & Meena, M.. (2016). Comparison of Behaviour of SCC Compression Members With and Without Steel Fibre. *SSRG International Journal of Civil Engineering (SSRG-IJCE)*, III(5).

Vasusmitha, R. & Rao, P.S.. (2013). Strength And Durability Study Of High Strength Self Compacting Concrete. *International Journal of Mining, Metallurgy & Mechanical Engineering (IJMMME)*, I(1).