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Table of Content

ISBN: 978-979-99723-9-2

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ISBN: 978-979-99723-9-2

ISBN: 978-979-99723-9-2

Parallel Session Schedule

Day/Date	Time	Room No	Paper ID
Wednesday 2 October 2013	13.00-15.00	1	AE-01, AE-06, UE-04, CE-06, CE-19
	13.00-15.00	2	IE-02, IE-04, IE-05, IE-06, IE-07
	13.00-15.00	3	IE-19, IE-21, IE-22, IE-23, ME-07
	13.00-15.00	4	ME-10, ME-11, ME-18, ME-20, ME-27, ME-34
	15.00-15.30		*Coffee Break*
	15.30-17.30	1	CE-07, CE-09, CE-11, CE-14, CE-18, CE-21
	15.30-17.30	2	EE-01, EE-02, EE-03, EE-04, EE-06, EE-08
	15.30-17.30	3	IE-10, IE-11, IE-12, IE-13, IE-16
	15.30-17.30	4	ME-12, ME-13, ME-17, ME-19, ME-26, ME-33
Thursday 3 October 2013	09.00-12.00	1	AE-02, AE-04, AE-07, AE-08, AE-09, AE-12, AE-14
	09.00-12.00	2	AE-13, AE-15, CE-03, CE-16, CE-20
	09.00-12.00	3	ME-01, ME-16, ME-22, ME-24, ME-29, ME-30, ME-31, ME-32
	09.00-12.00	4	IE-08, IE-14, IE-15, IE-17, IE-24, UE-01, UE-02, UE-03

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THE INFLUENCE OF ASPEC RATIO OF LOCAL FIBERS ON FLEXURAL PROPERTIES OF REACTIVE POWDER CONCRETE

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Abstract

Concrete is the most broadly used material in construction worldwide. One of the type of concrete is Reactive Powder Concrete with fibers that is a relatively new member of the high strength concrete family. The object of adding fibers into cement-based materials is to improve toughness, strain capacity, and to reduce the tendency of crack propagation. In this work the critical parameters of fiber reinforcement reactive powder concrete such as modulus of rupture and toughness are investigated. The efficiency of fiber reinforcement depend upon the fibre length, the orientation of the fibers, and the fiber-matrix shear bond strength. The type of fibers used in this investigation are stainless steel, the volume of fibers are 1,5% of the total volume and aspec ratio 75, 100, and 125 with 0,2 mm in diameter. The investigation shows that fiber with aspec ratio 100 results the best value of compressive strength, and fiber with aspec ratio 125 results the best value of modulus of rupture, and toughness of the concrete.

Keywords: fiber reinforced concrete, reactive powder concrete, flexural tests, toughness, aspec ratio.

INTRODUCTION

Concrete is the most broadly used material in construction worldwide. One of the type of concrete is Reactive Powder Concrete with fibers that is relatively new member of the high strength concrete family. The type of fibers such as steel, glass, polymer, and ceramic can be used in concrete. According to some research [7,8], steel fiber results the best value among another type of fibers. Local fiber is used in this work because the expectation to reduce the dependence to import material and to prove that local fiber can results the value close to another fibers.

Reactive Powder Concrete (RPC) is a type of ultra high strength concrete (200-800 MPa) and high ductility. Richard and Cheyrezy[1] indicate the following principles for developing RPC:

1. Elimination of coarse aggregates for enhancement of homogeneity.
2. Utilization of the pozzolanic properties of silica fume.
3. Optimization of the granular mixture for the enhancement of compacted density.
4. The optimal usage of superplasticizer to reduce w/c and improve workability.
5. Application of pressure (before and during setting) to improve compaction.
6. Post-set heat-treatment for the enhancement of the microstructure.
7. Addition of small-sized steel fibres to improve ductility.

Reactive Powder Concrete with fibers is a relatively new member of the concrete. The object of adding fibers into cement-based materials is to improve toughness, strain capacity and to reduce the tendency of crack propagation because of the loading.The addition of fibers into hydraulic cement base material also can improve two factors which are strength and toughness of composite materials. The two factors depend on the fibers length, orientation of the fibers, and the fiber-matrix shear bond strength[2].

The efficiency of fibers reinforcement depend upon the critical length. Critical length can be defined as the minimum fibre length required for the build-up of a stress (or

ISBN: 978-979-99723-9-2

load) in the fibre which is equal to its strength[2]. If the length of the fibers shorter or longer than the critical length, the fibers capacity to transfer stress become not efficient.

In this work, mini steel fibers which are usually used by foreign researcher is replaced by local mini steel fibers with the consideration of easy to get and the lower price. Mini steel fibers that been used in this work are stainless steel with tensile strength 515 MPa, shear strength 86 GPa. The diameter of the fibers are 0,2 mm and the length of 15 mm, 20 mm, 25 mm.

In this work the critical parameters of fiber reinforcement reactive powder concrete such as flexural strength and toughness are investigated. The flexural strength indicated by modulus of rupture using the third-point loading test method. Addition of fibers can also improve the value of toughness. Toughness is defined as the total energy absorbed prior to complete separation of the specimen. This energy can be measured by taking the area under the complete tension or compression stress-strain curve or by the area under the load-deflections curve in flexural. Studies have shown that the primarily parameters influencing toughness are the type, volume, aspect ratio, deformation, and orientation of the fibers[3]. Aspec ratio is the ratio of length and diameter of a material. Because of that factors, various number of aspec ratio are used to find out the proportional mix design to results the optimum flexural strength of Reactive Powder Concrete.

MATERIALS AND METHOD

Materials that been used in this studies are fine sand with 1,2 mm maximum in diameter, portland cement type 1, silica fume, superplasticizer, quartz powder, water, and stainless steel 304 0,2 mm in diameter. The shape of specimen that used in this studies are cylinder and beam. The size of specimens for the compressive test are 7,5cm in diameter, and 15cm in height. For the flexural test, the size of specimens are 10cm in width, 10cm in height, and 35cm in length.

The mix design of the fiber reinforced concrete are:

- Water cement ratio = 0,2
- Fine aggregate = 1,5x mass of cement
- Silica fume = 25% mass of cement
- Superplasticizer = 3% mass of cement
- Quartz powder = 30% mass of cement
- Aspect ratio of fibers = 75, 100, 125
- Volume of fibers = 1,5%

The method of specimen test:

- Compressive test for concrete cylinderØ7,5 cm x 15 cm.
- Flexural test for concrete beam 10 cm x 10 cm x 35 cm using Third-Point Loading Method[3].
- Slump test using Inverted Slump Cone Test Method[5].
- Toughness test using Flexural Toughness and First-Crack Strength Method[6].

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Table 1. Standard test method

Concrete	
Pengujian	Standard Test Method
Compressive Test	SNI 03-1974-1990
Flexural Test	SNI 03-4431-1997 / ASTM C78
Toughness	ASTM C1018
Slump test	ASTM C995

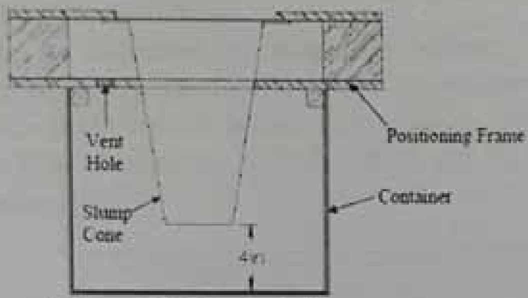

Figure 1. Inverted slump cone

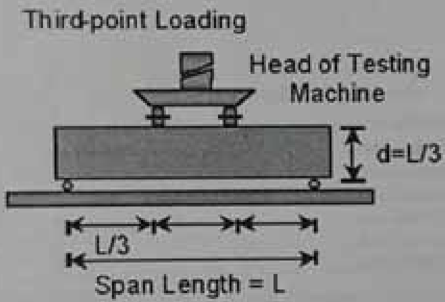

Figure 2. Third-point loading test method

Calculation of Compressive Strength

$$\text{Compressive Strength} = \frac{F}{A} \quad (1)$$

Note:
F = maximum loading (N)
A = luas penampang benda uji (mm^2)

Calculation of Modulus of Rupture

If the fracture initates in the tension surface within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = \frac{PL}{bd^2} \quad (2)$$

If the fracture ocurs in the tension surface outside of the middle third of the span length by not more than 5% of the span length, calculate the modulus of rupture as follows:

$$R = \frac{3Pa}{bd^2} \quad (3)$$

If the fracture occurs in the tension surface outside of the middle third of the span length by more than 5% of the span length, discard the results of the test.

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Note:

R = modulus of rupture (MPa)
P = maximum applied load indicated by the testing machine (N)
L = span length (mm)
b = average width of specimen (mm)
d = average depth of specimen (mm)
a = average distance between line fracture and the nearest support measured on the tension surface of the beam (mm)

Calculation of Toughness Indices

Toughness is indicated by toughness indices. These indices are determined by dividing the area under the load-deflection curve up to a specified deflection criterion, by the area up to the deflection at which first crack is deemed to have occured. Toughness indices (Figure 3) according to ASTM C1018 are I_5, I_{10}, and I_{20}, and residual strength factors are $R_{5,10}$dan $R_{10,20}$.

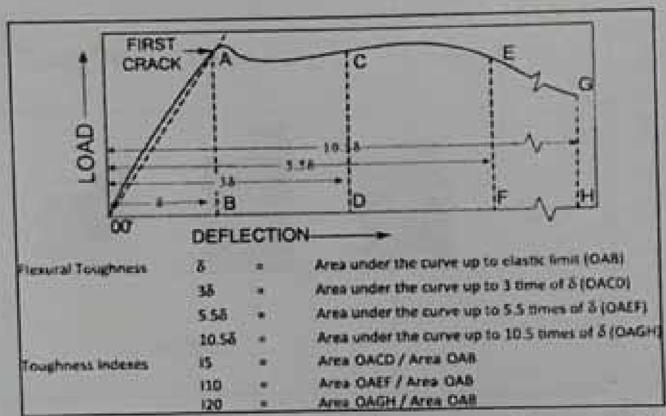

Figure 3. Calculation of toughness indices according to ASTM C1018

RESULTS AND DISCUSSION

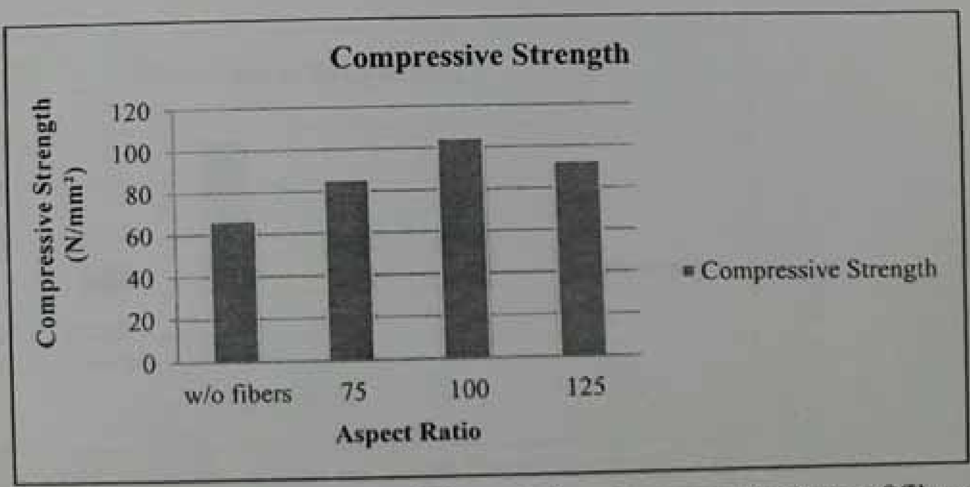

Figure 4. The compressive strength of fiber reinforced concrete (volume of fibers 1,5%)

As can be seen in Figure 4, the addition of fibers can increase the compressive strength of concrete up to 56,83%.

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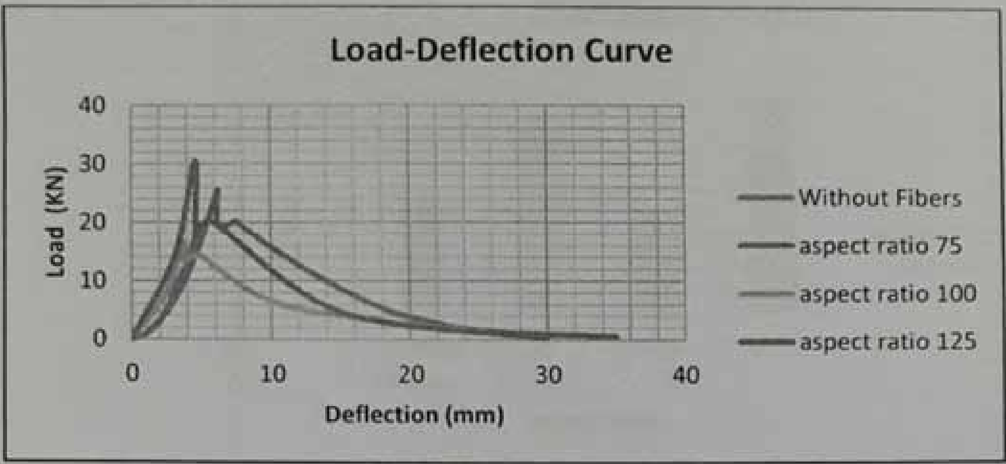

Figure 5. Load-deflection curve of fiber reinforced concrete (volume of fibers 1,5%)

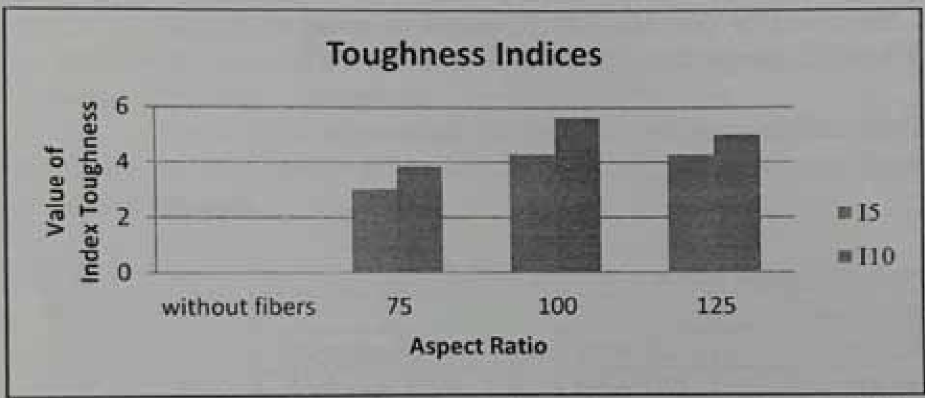

Figure 6. Toughness indices value of fiber reinforced concrete (volume of fibers 1,5%)

Figure 6 shown that the aspect ratio 100 results the best value of index toughness. That means, higher index toughness, higher the energy that absorbed after the first-crack.

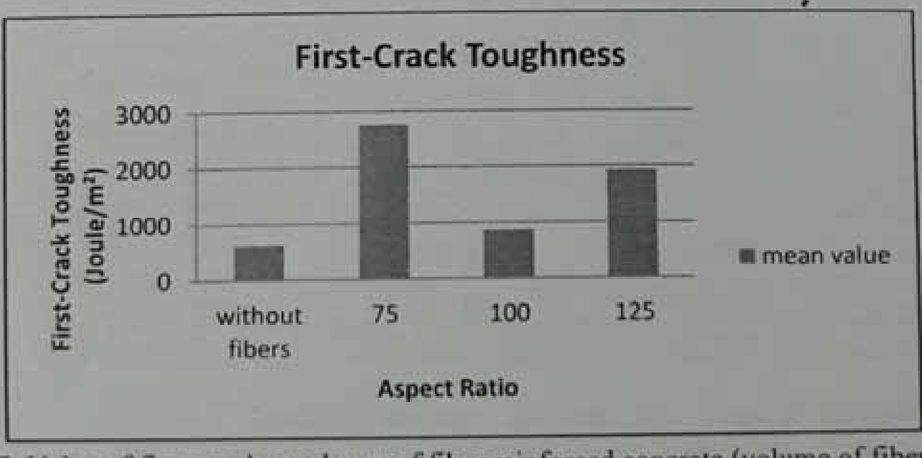

Figure 7. Value of first-crack toughness of fiber reinforced concrete (volume of fibers 1,5%)

The first crack toughness can be obtained by calculate the area under the first crack load and first-crack deflection curve.

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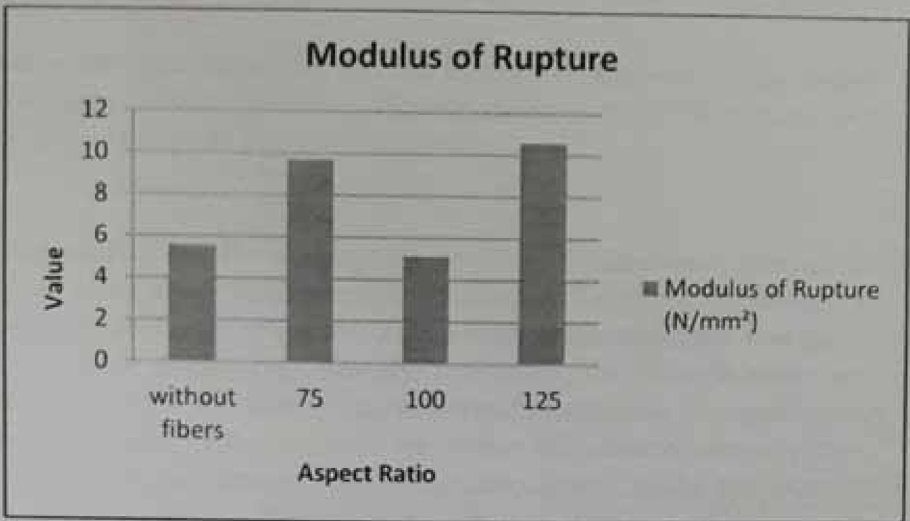

Figure 8. Value of modulus of rupture of fiber reinforced concrete (volume of fibers 1,5%)

As can be seen in Figure 8, the addition of fibers can increase the modulus of rupture of concrete up to 90,02%. Concrete with aspect ratio of fibers 125 results the best value of modulus of rupture.

The results of inverted slump cone test showed that the higher aspect ratio of the fibers, the workability of the concrete become lower because the matrix took longer time to empty the cone.

Table 2. The results inverted slump cone test

	Time (second)
Volume 1,5%, aspect ratio 75	93,62
Volume 1,5%, aspect ratio 100	95,98
Volume 1,5%, aspect ratio 125	118,09

Table 3. Comparison of the results of this work and previous research

	Researcher	Richard and Cheyrezy (RPC 200)[1]	Kim Huy Hoang et al [7]	Ju Yang et al [8]
Steel fiber	L: 15-25 mm Ø : 0,2 mm	L: 13 – 25 mm Ø : 0,15 – 0,2 mm	L: 17 mm Ø : 0,2 mm	L: 13 mm Ø : 0,2 mm
Volume of fibers	1,5%	1,5 -3%	1,5%	1,5%
Aspect ratio	75, 100, 125	85 - 125	85	65
Steam curing	90°C	20 - 90°C	90 – 100°C	90°C
Compressive strength	80-110 MPa	170 - 230 MPa	162,7 MPa	173 MPa
Flexural strength	4 – 11 MPa	30 - 60 MPa	19,1 – 23,4 MPa	15,54 MPa
Toughness	750 – 2700 J/m²	30*10³ J/m²	-	0,749 Nm

From Table 3, we can see that the addition of the fibers can increase the compressive strength of the concrete, modulus elasticity, and modulus of rupture. Concrete with aspect ratio 100 results the best value of compressive strength and index toughness among the other aspect ratio, but concrete with aspect ratio 125 results the best value of modulus of rupture and toughness indices that almost the same with concrete with aspect ratio 100. That can be happen because of the proses of making the concrete and the material that we used. The size of sand 1,2 mm was too big compared with the RPC

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specification that 0,6 mm in size that caused the void in the matrix. Because of this studies analyzed the influence of aspect ratio fibers on flexural behaviour of reactive powder concrete, the aspect ratio 125 was results the optimum value.

CONCLUSIONS

Conclusion of this studies are the addition of local steel fibers can increase the compressive strength of concrete up to 56,83% and the modulus of rupture of concrete up to 90,02%. The addition of fibers really influence the ductility of the concrete that can be seen in the load-deflection curve of concrete after the first-crack, the curve became non-linier. The higher toughness indices, the energy that absorbed also higher.The addition of fibers also influence the workability of the concrete, the higher the value of aspect ratio of fibers, the workability of the concrete become lower.The calculation results that concrete with fibers with aspect ratio 125 results the optimum value of modulus of rupture and toughness.

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