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Table of Content

Forewords: Chairman of the Organizing Committee	i
Forewords: Dean of Faculty of Engineering	ii
Forewords: Rector of Tarumanagara University	iii
Scientific Committee	iv
Organizing Committee	v
Table of Content	vi

Invited Papers

CFD modeling on Capillary Flow of Wave Soldering <i>M.S. Abdul Aziz, M.Z. Abdullah, C.Y. Khor, F. Che Ani</i>	1-8

List of Papers

Paper ID	Title Author/Authors	pp
AE-01	Exploring What Influences Motorcycle Use for Daily Travel with Theory of Planned Behavior <i>Siti Fatimah, B. Kombaitan, Gatot Yudoko, Tubagus Furqon</i>	1-8
AE-02	Existential Expression Of Extension Building In Children Library By Tadao Ando Is Spirit Of Age <i>Rudy Trisno, Antariksa, Sudikno, Purnama Salura</i>	1-7
AE-04	Virtual Gamer Space as the Possible Future City Shaper <i>Andi Surya Kurnia</i>	1-7
AE-06	Typology of Residential Architecture by Activity Microeconomics <i>Etty R. Kridarso</i>	1-12
AE-07	The Development Of Chinese Community (Pecinan) In Surakarta Cities, Central Java, Indonesia <i>Nafi'ah Solikhah</i>	1-9
AE-08	Fence Compromise Interests Of An Individual And The City <i>Franky Liauw</i>	1-8
AE-09	An Idea Planning Of The Urban Water-Based Development In The Indonesia's Cities Case Study: Tanjung Priok, The North Of Jakarta, Indonesia <i>Mekar Sari Suteja</i>	1-7
AE-12	The Role Of Building Pathology To Realize Eco-Housing <i>James Rilatupa</i>	1-9
AE-13	The Time Limit Parameters In Feasibility Study of Using Solar Panel For Household Energy Consumption In Jakarta <i>Melissa Kania</i>	1-8
AE-14	Sustainable Housing Development Along The River Bank Ciliwung River's Case: Problem As Solution <i>Darrundono</i>	1-4
AE-15	Water-Filled Window" Construction To Protect Sunlight Heat Propagation Into The Room <i>Fermanto Lianto</i>	1-16
CE-03	Students Perceptions On Trans Jakarta Services <i>Leksmono Suryo Putranto, Herry Hartanto</i>	1-7

Paper ID	Title Author/Authors	PP
CE-06	Understanding Travel Behavior In Motorcycle City From Household Activity Time Allocation <i>Okto Risdianto Manullang</i>	1-9
CE-07	Threat Of Environmental Degradation Due To The Exploitation Of Shale Gas Besides Great Potential Shale Gas In Indonesia <i>Sofyan Ramadhan, Hanif Indra Wicaksana</i>	1-7
CE-09	Soil Characterization Of Index Properties At Telecommunication Network Site In East Java, Indonesia <i>Marelianda Al Dianty, Ahmad Shukri Yahaya, Fauziah Ahmad</i>	1-6
CE-11	Comparison Of Road User Cost Loss Due To Work Zone With The Delay Completion Road Maintenance Project <i>Dewa Ketut Sudarsana, Harnen Sulistio, Achmad Wicaksono, Ludfi Djakfar</i>	1-8
CE-14	The Availability Of Shale As A Potential Of Mass Movement For Identifying The Consideration And Evaluation In A Construction, Case Study: Bukit Agung Regency, Gunungpati, Semarang <i>Widiastuti Nur Farida, Ghufrun Helmi Aziz, F.X. Anjar Trilaksono</i>	1-8
CE-16	To Increase The Damping On Passive Control Device By Using Asphalt Material <i>Daniel Christianto, Yuskar Lase</i>	1-8
CE-18	Implementation Of Viscosity Measurement On Plastic And Viscous Liquid State For Mudflow Case <i>Budijanto Widjaja, Shannon Hsien-Heng Lee</i>	1-7
CE-19	A High Dynamic Mobile Knowledge Worker: Preliminary Insight To The Impact Of The Smartphone On Travel Behavior. <i>Gloriani Novita C., Ofyar Z. Tamin, Idwan Santoso, Miming Miharja</i>	1-9
CE-20	The Influence of Aspect Ratio of Local Fibers on Flexural Properties of Reactive Powder Concrete <i>Widodo Kushartomo, Supartono, Cindy Angela</i>	1-7
CE-21	Funding And Financing Regional Road Maintenance In Indonesia <i>Tiopan Henry M Gultom, Ofyar Z Tamin, Pradono, Ade Sjafruddin</i>	1-11
EE-01	Performance Evaluation Of Zigbee Protocol Using Simulation Model <i>Lydia Sari, Theresia Ghozali</i>	1-6
EE-02	The role of the Indonesian universities in New & Renewable Energy <i>Rohani Jahja Widodo</i>	1-8
EE-03	Comparative Analysis Method For Enhancing The Quality Image Grayscale Bayesian Method Of Least Square Method Gaussian Scale Mixtures And Wiener <i>Nanniek Andiyani, Ainil Syafitri, Bektu Yulianti, Yohannes Dewanto</i>	1-8
EE-04	Home Security Integrated System By Using A Short Message (SMS) On Mobile Phones Using Microcontroller Atmega 8535 <i>Tobias, Bambang Widodo, Yohannes Dewanto</i>	1-7
EE-06	Telemetry System Design On Payload Using Flymapple with ARM Cortex-M3 <i>Izzah F. Akmaliah, Imam S Nugroho, Andriani</i>	1-6
EE-08	Four Kinds of Testing in Mobile Application "Diabetes Risk Application (DBRA)" <i>Anindito Yoga Pratama, Dewi Agushinta R., Remi Senjaya</i>	1-9
IE-02	Analysis Of Effect Of Body Mass Index (BMI) And Surface Area Of The Heel On Female Prospective Employee During Walking <i>Andrijanto, Ririn Nalurita</i>	1-7

Paper ID	Title Author/Authors	pp
IE-04	Distance Estimation Within Peri-Personal Space In Real And Virtual Environment <i>Dino Caesaron, Chiuhsiang Joe Lin</i>	1-5
IE-05	Silver Meal And Part Period Algorithm In Producing Minimum Lot Sizing Cost <i>Hendy Tannady</i>	1-4
IE-06	Imovation: Innovative, Safe, And Ergonomically Suitable Tool For Active Elderly People To Climb Stairs. <i>Ardian Domingo W., Vicario Reinaldo, I Gusti Agung Gede S., Fajar Wisma P.</i>	1-7
IE-07	Decision Support Tool For Job Shop Scheduling With Job Cancellation <i>Muchamad Oktaviandri, Adnan Hassan, Awaluddin Mohd. Shaharoun</i>	1-8
IE-08	Analysis of Application Low Cost Automachine on Product Type Switch ASL on PT. Omron Manufacturing of Indonesia <i>Silvi Ariyanti, Ruly</i>	1-12
IE-10	Urban Engineering: Urban Search And Rescue (USAR) Within Emergency Response Systems In Confined Space Rescue Using Serpentine Robot <i>Khristian Edi Nugroho Soebandrija, Sofyan, Andre M.R. Wajong, Meilani</i>	1-6
IE-11	Airport Of The Future, Green Airport And Aerotropolis: Industrial Engineering And Architecture Engineering Perspective <i>Khristian Edi Nugroho Soebandrija</i>	1-7
IE-12	Industrial Engineering And The Perspectives On Leadership, Performance, Innovation, Competitive Advantage And Sustainable Competitive Advantage <i>Khristian Edi Nugroho Soebandrija</i>	1-7
IE-13	Framework Design for Standard Operating Procedures (SOP) Implementation of Cultivation And Post-Harvest In Cluster Biopharmaca Karanganyar. <i>Novita Hadiningrum, Retno Wulan Damayanti, Fakhrina Fahma</i>	1-8
IE-14	Time Study At Packing Cable Work Station, Case Study At PT. X <i>I Wayan Sukania, Handika</i>	1-6
IE-15	Designing Questionnaire for Empirical Study on Relationship Between TQM, TPM, and KM <i>Wilson Kosasih</i>	1-5
IE-16	Model Development of Shifting Bottleneck Heuristic to Solve Job Shop Scheduling Problem With Parallel Machines <i>Johan Oscar Ong, Imam Maulana</i>	1-6
IE-17	Transformer Oil Insulation Analysis Based On Breakdown Voltage Testing At PT. PLN (PERSERO) Service And Production Semarang <i>Mohammad Agung Saryatmo</i>	1-10
IE-19	Using Augmented Reality to Enhance Art Exhibition at Binus International <i>Raymond Bahana, Bayu Prakoso Dirgantoro</i>	1-5
IE-21	Ergonomics Analysis The Porters Complaints Against The Occurrence Of Musculoskeletal Disorders (MSDs) Using The Niosh Lifting Equation And PEI <i>Boy Nurtjahyo M., Erlinda Muslim, Krisna Anga Ramadha, Debrina Puspitarini</i>	1-8
IE-22	Recommendation Of Unloading Process Equipment In Raw Material Store Of Fast Moving Consumer Goods Plant With Virtual Human Modeling Methodology <i>Erlinda Muslim, Boy Nurtjahyo M., Herman Adrian, Yiky Muruatut</i>	1-8

Paper ID	Title Author/Authors	pp
IE-23	Designing Ergonomic Packaging Line Workstation With Simulation Methods <i>Maya Arlini Puspasari, Erlinda Muslim, Feronika, Atiqah Zulfa Nadia</i>	1-7
IE-24	Line Assembly Analysis For R-223 Product By Kilbridge-Wester Heuristic Method, Helgeson-Birmie Method And Moodie Young Method At PT. Mulia Knitting Factory <i>Lina Gozali, Silvi Ariyanti, Elizabeth Maria</i>	1-11
ME-01	Elastic Normal Contact Of A Rough Surface With Interaction Between Asperities Using Elastic Halfspace Theory <i>Rugerry Toni Liong</i>	1-8
ME-07	Sampling Tools Product Design Process On Pre Heater Process In Cement Production <i>Edi Sutoyo, Yohanes Dewanto, Agri Suwandi</i>	1-7
ME-10	Solarcell Design Inverter To Supply The Load At 50 W, 50 Hz <i>Syahrul Alamsyah, I.A. Daryanto D., Munnik H., Yohannes Dewanto</i>	1-6
ME-11	New And Renewable Energy By Using Magnets To Generate Electricity <i>Dzulfi S. Prihartanto, Suharlan, Gede Eka Lesmana, Yohannes Dewanto</i>	1-6
ME-12	Model Of Charge Carrier Rocket Launcher On Research Measuring Pressure, Temperature, And Humidity <i>Mochammad Ilham Attharik, Ahmad Hidayat Furqon, Pinardi, Eko</i>	1-6
ME-13	The Use Of Ramie Fiber In HDPE Matrix Composite For The Rehabilitation Of Scoliosis Patients <i>Lies Banowati, Bambang Kismono Hadi</i>	1-5
ME-16	The Effects An Environment Can Cause On Low Alloy Steel at A Variety of Temperatures <i>Erwin Siahuan</i>	1-10
ME-17	Effect Of Different Bend-Twist Coupling Topologies on Induced Twist and Cost of Wind Turbine Adaptive Blades <i>Rahul Bagali, Hui Zhang, Alireza Maheri</i>	1-7
ME-18	Updated Cost Modeling Of Hybrid Renewable Energy System Components <i>Fadi Kahwash, Alireza Maheri</i>	1-7
ME-19	A Genetic Algorithm For Optimal Distribution Of Aerofoils On Wind Turbine Blades <i>Fadi Kahwash, Alireza Maheri</i>	1-7
ME-20	Thermal Properties Analysis Of Multy Component Material As Thermal Energy Storage Material <i>Suditama, Budhi S.K.</i>	1-9
ME-22	Expert System In Design Automation For Customized Product Development - Three Degree Of Freedom Vertical CNC Milling Machine <i>Agus Halim, Didi Widya Utama, Jemmy Septiawan</i>	1-8
ME-24	Effect of Rake Angle in the Turning Process on the Surface Roughness of Workpiece AISI 4340 Steel <i>Sobron Lubis, Rosehan, Denny Handoko</i>	1-9
ME-26	Joint Properties Of Friction Stir Welded 6063 t3 Aluminum Alloys With Variation Of Preheat Method <i>Yustiasih Purwaningrum, Medilla Kusriyanto, Lulu Supriyanto</i>	1-6
ME-27	Experimental Study Characterization Burner Gas Flame Bioethanol Sago Residual <i>I Made Kartika Dhiputra, Numberi Johni Jonatan</i>	1-4
ME-29	Design Concept Of Fifo Pick And Deposit System <i>Richard Jonathan Salli, Agustinus Purna Irawan, Danardono A.S.</i>	1-7

Paper ID	Title Author/Authors	pp
ME-30	Comparison Of Turbulence Models On Reynolds Numbers Of A Proto X-2 Bioenergy Micro Gas Turbine's Compressor Discharge <i>Steven Darmawan, Ahmad Indra Siswantara, Budiarmo</i>	1-9
ME-31	Polymer Matrix Composite Mechanical Properties Of Two Types Woven <i>Sofyan Djamil, Sobron Y Lubis, Hartono</i>	1-5
ME-32	Cooling Effect of Capillary Tube in Refrigerator <i>Harto Tanujaya</i>	1-5
ME-33	Enhancing the Perfomance of Corrugated Panels Under Blast Loading: Numerical Analysis <i>Christian Wijaya, Johan Oscar Ong</i>	1-2
ME-34	Energy Efficient Cold Storage As Hybrid Refrigeration Machine Using Heating Effect From Condenser With Hydrocarbon Refrigerant Substituted For R-22 <i>Azridjal Aziz, Herisiswanto, Afdhal Kurniawan Mainil</i>	1-8
UE-01	To Promote Jakarta City as one of an excited Tourist Destination in Asia towards the Asian Economic Community (AEC) <i>Priyendiswara</i>	1-8
UE-02	Innovative Use Wood And Bamboo Use As Renewable Finishing Materials In The Building Application <i>Sylvie Wirawati</i>	1-8
UE-03	Evaluation Of 25 Years Of Development Of The New Towns In Jabodetabek: Profile <i>Liong Ju Tjung, Suryono Herlambang, Indah Susilowati, Regina Suryadjaja</i>	1-10
UE-04	The Lineage Of Ict Development: The Case Of Batam Island <i>Adiwan Aritenang</i>	1-5

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		<i>Coffee Break</i>
	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

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

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]. Aspect ratio is the ratio of length and diameter of a material. Because of that factors, various number of aspect 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 cylinder $\varnothing 7,5$ 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].

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

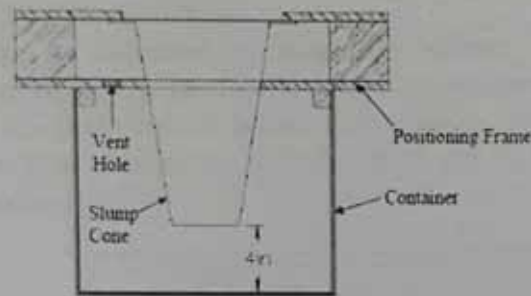


Figure 1. Inverted slump cone

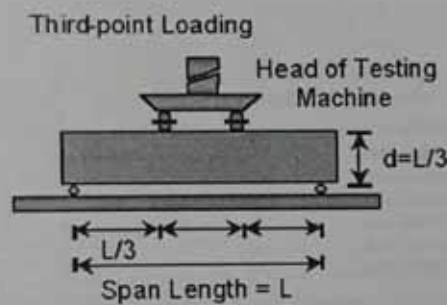


Figure 2. Third-point loading test method

Calculation of Compressive Strength

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

Note:

F = maximum loading (N)

A = luas penampang benda uji (mm²)

Calculation of Modulus of Rupture

If the fracture initiates 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 occurs 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.

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 occurred. 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 $R_{10,20}$.

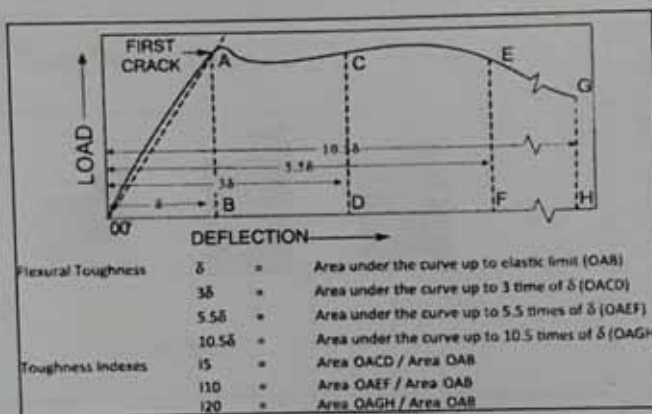


Figure 3. Calculation of toughness indices according to ASTM C1018

RESULTS AND DISCUSSION

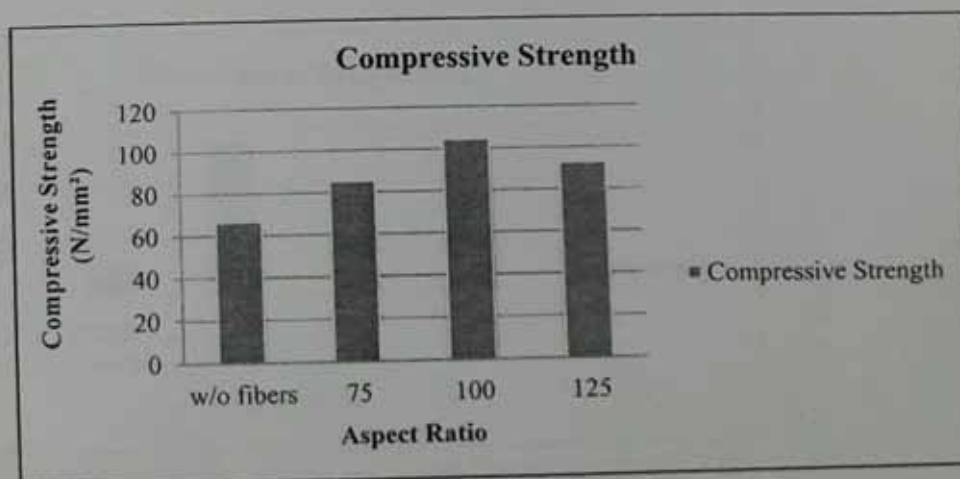


Figure 4. The compressive strength of fiber reinforced concrete (volume of fibers 1,5%)

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

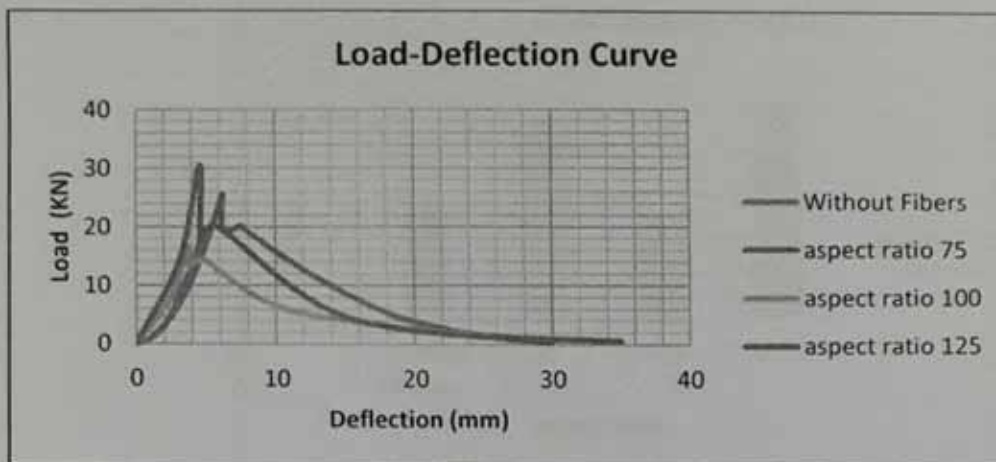


Figure 5. Load-deflection curve of fiber reinforced concrete (volume of fibers 1,5%)

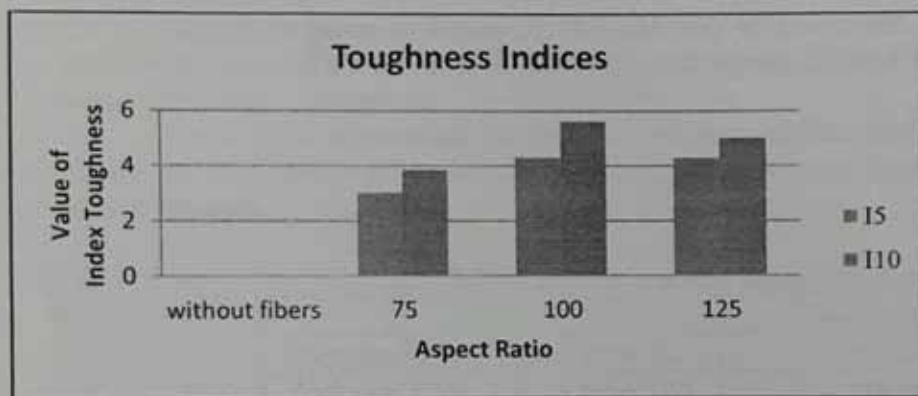


Figure 6. Toughness indices value of fiber reinforced concrete (volume of fibers 1,5%)

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.

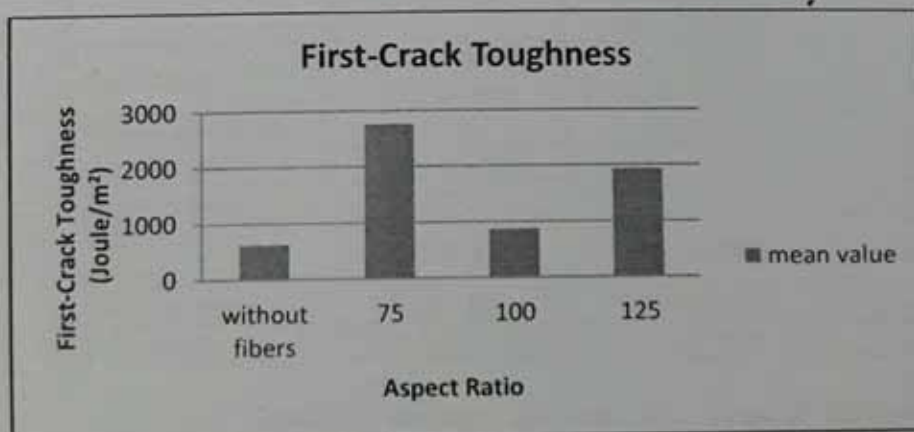


Figure 7. Value of first-crack toughness of fiber reinforced concrete (volume of fibers 1,5%)

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

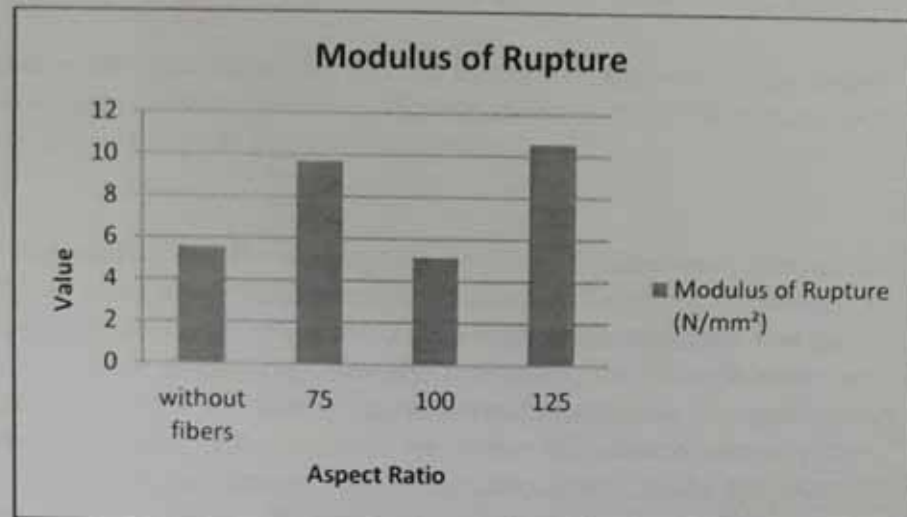


Figure 8. Value of modulus of rupture of fiber reinforced concrete (volume of fibers 1,5%)

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/m ²	30*10 ³ J/m ²	-	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

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-linear. 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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