Increasing Ductility Of High Bar-Boned Concrete By Adding Roving Fiber Into Concrete Mortar

Henry Apriyatno[1]

[1]*Civil Engineering Department,Faculty of Engineering,Semarang State University*

Abstract *— Concrete has been used in various constructions for it obsesses many benefits. It is easy to obtain and it has a high compressive stress. However, concrete lacks in it tensile strength and ductility. But those weaknesses can be decreased by adding fiber in the concrete mortar. The purpose of this research is to see the effect of adding roving fiber in the amount of 4%, 6% and 8% of the concrete volume, with the length of the fiber is 6 cm and f.a.s 0,6., against the concrete compressive strength (f_c), concrete split tensile strength (f_t), modulus of concrete elasticity (Ec), deflection and crack length.*

The test device used in this research will include 12 concrete cylinders with each size is 150 mm x 300 mm – which are used for a test of concrete compressive strength (f'_c), concrete split tensile strength (f_t) and modulus of concrete elasticity (Ec) - and three high bar-boned concretes with each size is 150 mm x 400 mm x 900 mm – which are used for examining the size of deflection and crack length.

Based on the research, it is found that the tensile strength for each 4% ,6% and 8% of roving fiber is decreased in the amount of 7,61 %, 14,349 % and 19 % compared to the normal concrete tensile strength; the modulus of concrete elasticity of each 4% 6%, and 8% roving fiber is decreased in the amount of 1,38 % ; 5,786% and 16,252% compared to the normal modulus of concrete elasticity. The result of the test also showed that each split tensile strength of 4%, 6% and 8% of roving fiber is increased in the amount of 6,03%, 8,274 % and 11,292 %, compared to the normal concrete. By adding 4% ,6% and 8% of Roving fiber into the concrete high bar, it can decrease cracks on the concrete as much as 8,936%, 15,697% and 25%; it also increase the deflection size as much as 1,423%, 21,751% and 41,806%. Accordingly, the adding of roving fiber will decrease concrete compressive strength in the amount of 14% and increasing concrete tensile strength in the amount of 8%. It also decrease the amount of cracks in the concrete as much as 16,544% and increasing bar deflection as much as 21,66%. In conclusion, concrete with added roving fiber has better ductaility compared to normal concrete bar.

Keywords *— high beam, ductaility, crack, roving, fiber.*

I. BACKGROUND

A beam is the greatest area that accepts the bending and shear loads. A normal beam is generally quite unable to withstand the shear force, therefore it needs to use high beam to overcome this issue. With the high beam, the shear force can cause cracks that will horizontally spread toward the center of the beam span.

One of several ways to improve the shear strength is the addition of fiber onto the concrete mix. It aims to give the bones to the concrete with fibers that are evenly mixed into the concrete with random orientation, as the result it is expected to prevent the micro cracks because of axial force, shear force or bending moment (Sehendro, B, 2000). There are a variety of fibers that can be added to concrete mix, such as roving fiber i.e. a fiber type that is widely used in the gypsum manufacture. In addition, roving fiber is also used for coating in painting, either in wall or roof tile painting, and vehicle bumper; it is aimed to get more rigid finished-objects.

High beam has a different condition from ordinary or normal beams. The flexural strength of high beams is far greater than the flexural strength of normal beam, it is because the high beam has a comparison of beam span size and effective height of beam, $2 \le ln/d \le 5$ (where*ln*is the length of beam span and *d* is the height of beam). Therefore, the flexural strength is high while the shear strength is low (SK-SNI-T-15-1991-03). The objective of this study are to determine the effect of the addition of roving fiber 4%, 6% and 8% of the volume of high beamconcrete with fiber length of 6 cm and 0.6 fas towardthe shear strength and to determine the ductility of beam and the control of long cracks.

II. REVIEW OF STUDY

II.1. Fiber Concrete

Fiber concrete is concrete composite consisting of normal concrete and other materials of fibers. The main purpose of the addition of fiber to concrete is to increase the tensile strength of concrete. The general formsof fiber are rods with diameters between 5 and 500 micro-meters, and a length of about 25 mm to 100 mm. The existence of fibers in concrete is useful to prevent cracked, thusit is expected that the fiber concrete is more ductile than normal concrete (Tjokrodimuljo, 1996).

II.2. Bonded-Concrete Beam

Beamis a portal element or structure that works as a unity in the portal to resist the bending, shear and torsion. Based on the comparison between the span length andbeam height, the bonded-concrete beams can then be divided into three kinds, namely: 1) beam with the ratio of size $\ln/d$ > 5, called the normal beam. 2). Beams with the ratio of size $2 \leq \ln/d \leq 5$, called the high beam. 3). Beam with the ratio of size $\ln/d$ <2, called very high beam; where *ln* is the beam span and *d* is beam height.

II.3. Compressive Strength (f'c)

Compressive strength of concrete is the amount of load per unit area that causes concrete specimen broken when it is loaded with a certain compressive force which is generated by a pressing machine SK SNI M-14-1989-F).

II.4. Split Tensile Strength(ft)

Split tensile strength (*ft*) is the tensile strength of concrete which is determined by the splitpress strength of the cylinder concrete that is pressed on the long side. (SK SNI-M-60-1990-03). A good approach to calculate the tensile strength of concrete *ft* is the formula 0.10 $f'c<ft<0.20\ f'c$. Tensile strength is more difficult to measure than the compressive strength due to gripping on the machine.

II.5. Shear Strength (Vc)

Shear strength is the strength of a structural component of the section which serves to increase the rigidity of the structure and to prevent lateral forces. The shear force will occur along the structural components which shear force works, and the section of components undergo shear force in the places other than on the neutral line and the edge of the section fiber. At the high beam, bending will occur immediately after the sloping crack, the load is prevented by press force structure forming arc that is tied by gravity along the bonded longitudinal (Chu-Kia Wang and Charles-G.Salmon, 1993).

II.6. Modulus of Elasticity of Concrete (Ec)

Modulus of elasticity of concrete is a comparing coefficient between stress and strain in elastic condition. The amount of concrete elasticity condition is at ¼ - ⅓ of its compressive strength (*f'c*), so the data analysis requiresup to ⅓ of the compressive strength of concrete (Dipohusodo, I, 1999).

II.7. Roving Fiber

Rovingfiber is one of the materials that is easy to get and the price is quite cheap; it has a density of 364 kg/m^3 Bj. If it is added to the concrete mix, it can change the properties of fresh concrete to be suitable for a particular work, or economical for other purposes such as increasing the ductile of concrete. Roving fiber as building materials meets the general requirements such as density of 900 kg/m, tensile strength of 35 MN/m, the coefficient of linear expansion 11x10 m/c, the maximum temperature for opisthokonta 65 (SK SNI S-04-1989-F).

Fig 1. Roving Fiber

II.8. Shear Capacity Test of High Beam

Shearing in the high beam is generally because the damage in area along approximately three time of effective high beam; and it is called shear span. Bending stress and shear stress will occur at high beam with a comparison between the stretch with high beam is $2 \leq \ln/d \leq 5$. (SK SNI-T-15-1991-03).

To determine theshearcapacity occurs, a test should held which can illustrate how thehigh beamonly accept the shear force,that is by putting ablockon thefoundation ofthejoint-roller placement. The loads incurredon thebeamisa concentrated loadat the mid of span(*1/2 l*). SeeFigure 2.

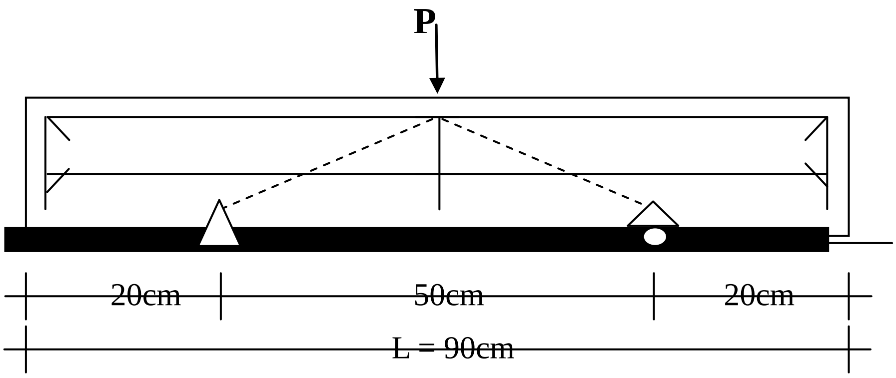


Fig 2. Beamlongitudinaltestpieces

III. RESEARCH METHOD

The research methods used in this study are experiment and observation on the specimen which include materials testing, compressive strength testing, elasticity modulus testing, shear capacity testing, split tensile strength of concrete testing, deflection and high beam concrete crack length and roving testing. The variables of study include roving fiber composition of 0%, 4%, 6% and 8% of the volume of concrete with the length of roving fiber is 6 cm and 0.6 fas. The number of each cylinder are 12 cylinders and bonded-concrete high beam with 15 CMX 40 cm x 90 cm are 3 beams.

IV. RESEARCH FINDINGS

The results of roving fiber concrete 4%, 6% and 8% showed a decrease in compressive strength (fc), respectively by 7.61%, 14.349% and 19.2% (Table 1). This decline occurred partly due to roving fiber density at 364 kg/m3 is lower than the density of coarse aggregate at 2591 kg/m3. Observation of test results of compressive strength of concrete cylinder did not show a broken roving fiber meaning that the specimen rupture was caused by the loss of coherence of cement interaction, aggregate and roving fiber.

TABLE 1. COMPRESSIVE AND SPLIT TENSILE STRESSES

No	Fiber Weight %	Compressive Stress MPa	Decline of Comp. Stress %	Split Tensile Stress MPa	Increase of Tensile Stress %
1	0	24,817	0	2,500	0
2	4	22,928	7,61	2, 652	6,037
3	6	21,256	14,349	2,707	8,274
4	8	20,052	19,2%	2,782	11,292

Table 2 showed the modulus of elasticity of concrete as a coefficient comparison between stress and strain in elastic condition. Concrete elastic was obtained about ¼ - ⅓ of its compressive strength (*f'c*); in the analysis of research data it was used ⅓ of the compressive strength of concrete (*f'c*). The results as in Table 2 showed that the modulus of elasticity of concrete of roving fiber were 4% 6%, and 8% respectively decreased by 1.38%, 5.786% and 16.252% of the modulus of elasticity of normal concrete; thus the research results were in line with the theory of modulus of elasticity i.e. modulus elasticity will decrease proportionally to the decrease of stress and the increase of strain. The results of split tensile strength showed the increase split tensile strength of concrete cylinders at the fiber composition of 4%, 6% and 8% respectively 6.037%, 8.274% and 11.292% of the normal concrete (Table 1).

TABLE 2. MODULUS OF ELASTICITY

Concrete Weight %	Ec	Decrease %
0	20495	0
4	20212	1,380
6	19309	5,786
8	17164	16,252

TABLE 3. STRESS AND STRAIN

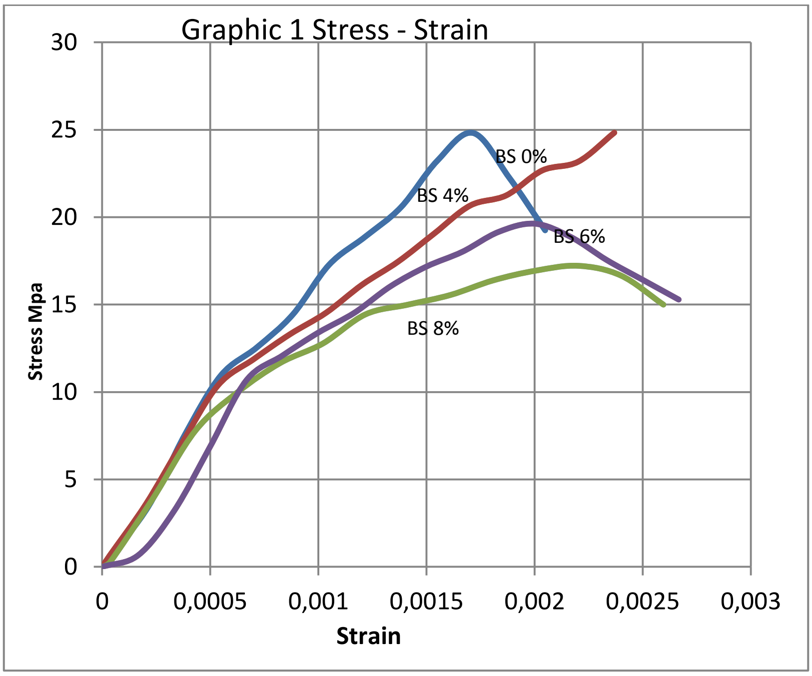
Concrete Weight %	Compressive Stress MPa	Strain
0	24,817	0,00172
4	22,928	0,00170
6	21,256	0,00175
8	20,052	0,00182

The increase intensile strength significantly caused the ability of the beam reaching deflectionis 21% greater than normal concrete(Figure2 andTable 4); thus the beam with roving fiber is more ductile than normal concrete beams. The result of observation of concrete cylindrical specimens showed the rupture of the concrete caused by the loss of the coherence of cemen tinteractions, aggregate and roving fiber, and also some broken roving fibers. While broken concrete cylinders were not decomposedas innormal concrete, thus roving fibe rcan increase the split tensile strength of concrete.

TABLE 4. DEFLECTION AND CRACK LENGTH when Pmax is normal concrete

No	Concrete Weight%	Max Load (P Kg)	Deflection Cm	Crack Length Cm
1	0	24 810	0,277	41,000
2	4	24 810	0,281	37,336
3	6	24 810	0,354	34,564
4	8	24 810	0,476	30,752

Graph 1 showed the relationship between linear stress and strain for normal concrete and roving fiber concrete 4% of linear strain up to 30% of linear stress, while for roving fiber concrete 6%, linear graphic only up to 3% stress, and whileat the roving fiber concrete8% does not find the linearity. It can be concluded that the higher content of roving fiber then the achieving of the strain linearity will be lower. The low linearity of stress-strain suggested that the role of roving fiber in concrete. Linear graph meant that the coherence between aggregate, fiber and cement were still solid/working, but at a higher level of stress, 30% of the initial stress of graphic had not been linear anymore either in normal concrete and fiber concrete. When the normal stress of concrete reached 20 MPa, the strain would reach around 0.00125, while roving fiber strain reached about 0.0017, the normal stress of concrete had reached the peak as indicated by the charts began to decline, while the stress of roving fiber concrete reached peak when strain reached at 0.002 and the graph had not decreased beyond the strain of normal concrete thereby roving fiber concrete gave the better results of ductility than normal concrete.



When the beams got loads, thus the inner stress was evenly distributed to all concrete matrices. Because the aggregates have been qualified as normal concrete (inside of concrete, the aggregate will not break), the stress distribution in the concrete will be forwarded to the juxtaposition between coarse aggregate and cement. When the distribution of inner stress wasbeyond the strength of the cement bonding, the function of cement bonding would then lose causing the cracks in the concrete which would be initiated with micro cracks and increased linearly toward the stress until the cracks were visible. With the existence of roving fiber concrete, energy releasing of cement to aggregate was diverted to roving fiber. This would delay the cracks until the inner stress significantly increased to interfere the cement bonding of aggregate roving fiber and the rupture of roving fiber causing visible cracks. The shear collapse of the high beam was indicated with cracks spreading from the pedestal to the load center. The results of observations in the high beam cracks started from the pedestal propagated to the center style.

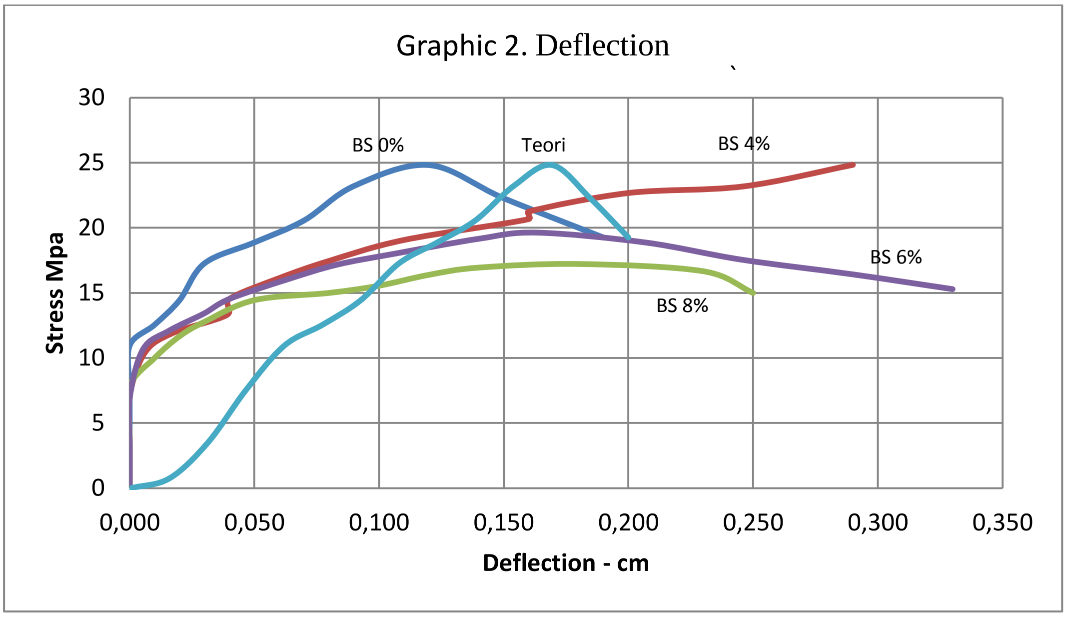
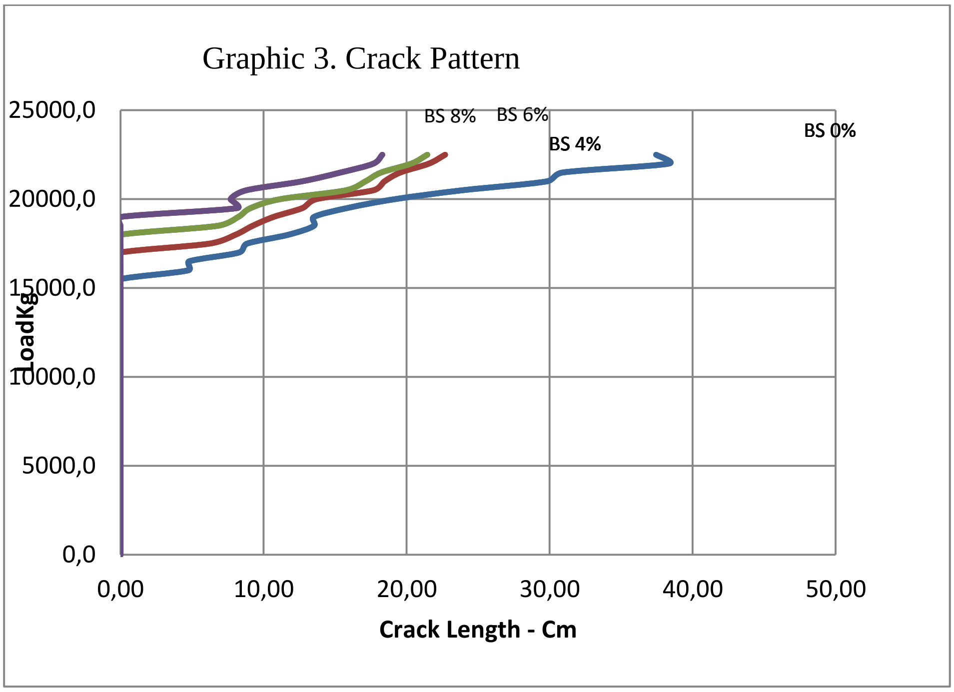


Figure 2. Image of the result of high beam specimen testing

Cracks were initiated when the stress reached about 10% propagated to middle of span, fiber concrete fragments were visible and did not fall compared to the cracks in normal concrete beam.The cracks in concrete beams with roving fibers seemed slow when crack length reached 5 cm. The loads that can be accepted by a concrete beam with roving fiber were lower than normal concrete beams that was only about 30% of normal concrete weight. From Figure 2, it was showed that the pattern of cracks was in line with the theory of the shear crack i.e. propagating tangentially to the object surface that was parallel to the direction of the force. Therefore, it could cause the shear stress on the object. The fragments on the surface of the pedestal and the load of beam showed that dominant of shear stress occured in concrete beams rather thank in bending stress. This meant that the simple shear stress had occurred when the action of a shear force on the beam emerged and was distributed to a broad cross section that was parallel/tangential with working shear force (Figure 3 and Figure 2).



V. CONCLUSION

The research results of roving fiber concrete 6 cm and fas 0.6 showed the average decline of compressive stress at 14% and the average increase of tensile at 8%. Modulus of elasticity fell by an average of 6%. The significant increase of tensile strength caused the ability of roving fiber beam reached 21.66% greater deflection than normal concrete. The pattern of roving fiber concrete underwent the deceleration by 70% compared to normal concretebeam and the type of cracks at roving fiber concrete is not falling compared to the normal concrete beam. Therefore, it can be concluded that the addition of roving fiber at concrete beam can increase the ductility.

BIBLIOGRAPHY

[1] Chu-Kia-Wang & Charles G.Salmon, 1993, *Desain Beton Bertulang*, Erlangga,Jakarta.

[2] Budiarto, A., 2006. *Pengaruhpenambahan roving fiber sebesar 6 % terhadap dari berat semen Terhadap Kuat Lentur Balok Beton Bertulang dengan fas 0,6*. Skripsi Jurusan Teknik Sipil Fakultas Teknik Universitas Negeri Semarang: Semarang.

[3] Dipohusodo, I. 1999. *Struktur Beton Bertulang Berdasarkan SK SNI-T-15-1991-03 Departemen Pekerjaan Umum.* PT Gramedia Pustaka Utama: Jakarta.

[4] Henry Apriyatno.,2008., *Pengaruh Penambahan Serat Roving Sebesar 6% Dari Volume Beton Terhadap Kuat Geser Balok Tinggi Beton Bertulang,* MakalahJurusan Teknik Sipil, FT UNNES Semarang.

[5] Henry Apriyatno.,2009., Kapapasitas *Lentur Balok Beton Bertulang Dengan Polypropylene Fiber Sebesar 6% Dari Berat Semen*, Jurnal Teknik Sipil Perencanaan FT UNNES.

[6] Henry Apriyatno,2010.,*Kapasitas Geser Balok Beton Bertulang Dengan Pyliproplylene Fiber Sebesar 4% Dari Volume Beton,* , Jurnal Teknik Sipil Perencanaan FT UNNES.

[7] Henry Apriyatno,2011,*Kapasitas Lentur Balok Beton Bertulang Dengan Penambahan Serat Sabut Kelapa (Coconut Fiber) Secara _Parsial Sebesar 1% Dari Volume Beton*.,2011.,Jurnal TERAS FT UNISIQ, Wonosobo,Jateng.

[8] Hidayat, D., 2006, *Pengaruhpenambahan roving fiber 6 cm terhadap lendutan balok beton bertulang dengan kadar serat 2% dari berat semen 400 kg/m^{3}dengan fas 0,6*. Skripsi Jurusan Teknik Sipil Fakultas Teknik Universitas Negeri Semarang: Semarang.

[9] Yudha S, 2008, *Pengaruh Penambahan Serat Roving Sebesar 10% dari Volume Beton Terhadap Kuat Geser Balok Tinggi Beton bertulang dengan fas 0,6,* Skripsi Jurusan Teknik Sipil Fakultas Teknik Universitas Negeri Semarang : Semarang.

[10] Kurniawati, A, 2006, *Pengaruh penambahan serat roving sebesar 8% dari berat seman pada sifat mekanis balok beton bertulang dengan fas 0,6*. Skripsi Jurusan Teknik Sipil Fakultas Teknik Universitas Negeri Semarang : Semarang.

[11] Novan Wibowo, 2008, **"***Pengaruh Penambahan Serat Roving Sebesar 4% Dari Volume Beton Terhadap Kuat Geser Balok Beton Bertulang Dengan fas 0,6",* Skripsi Jurusan Teknik Sipil, Fakultas Teknik, Universitas Negeri Semarang.

[12] Paul Nugroho & Antoni, 2007, *Teknologi Beton,* CV.Andi Offset: Yogyakarta.

[13] SK SNI M-14 1989-F, 1989, *Tata Cara Pengujian Kuat Tekan Beton)*. Bandung : DPU-Yayasan LPMB.

[14] SK SNI M-60-1990-03, 1990, *Tata Cara Pengujian Kuat Tarik Beton*. Bandung : DPU-Yayasan LPMB.

[15] SK SNI T-15-1991-03, 1991, *Tata Cara Perhitungan Struktur Beton Bertulang untuk Bangunan Gedung*. Bandung : DPU-Yayasan LPMB.

[16] Sudarmoko, 2000, *Beton Fiber Lokal untuk Non-Struktural*. Pusat Antar Universitas Ilmu Teknik Universitas Gajah Mada: Yogyakarta

[17] Suhendro, B. 2000. *Beton Fiber Konsep, Aplikasi, dan Permasalahannya*. Pusat Antar Universitas Ilmu Teknik Universitas Gajah Mada: Yogyakarta.

[18] Tjokrodimuljo, K. 1996. *Teknologi Beton.* Yogyakarta : Nafiri.

[19] Usmanto, W. 2006. *Pengaruh penambahan serat roving sebesar 4% dengan panjang serat 6 cm pada sifat mekanis balok beton bertulang.* Skripsi Jurusan Teknik Sipil Fakultas Teknik Universitas Negeri Semarang.