Review of Carbon Fiber Reinforced Polymer Reinforced Material in Concrete Structure

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Abstract— **Carbon Fiber Reinforced Polymer (FRP) is a material that is lightweight, strong, anti-magnetic and corrosion resistant. This material can be used as an option to replace the steel material in concrete construction or as material to improve the strength of existing construction. CFRP is quite easy to be attached to the concrete structure and proved economically used as a material for repairing damaged structures and increase the resilience of structural beams, columns, bridges and other parts of the structure against earthquakes. CFRP materials can be shaped sheet to be attached to the concrete surface. Another reason is due to the use of CFRP has a higher ultimate strength and lower weight compared to steel reinforcement so that the handling is significantly easier. Through this paper suggests that CFRP materials can be applied to concrete structures, especially on concrete columns. Through the results of experiments conducted proved that the concrete columns externally wrapped with CFRP materials can increase the strength. This treatment is obtained after testing experiments on 130 mm diameter column with a height of 700 mm with concentric loading method to collapse. The experimental results indicate that a column is wrapped externally with CFRP materials can achieve a load capacity of 250 kN compared to the concrete columns externally without CFRP material which only reached 150 kN. If the column is given internally reinforcing steel and given externally CFRP materials can reach 270 kN. It shows that CFRP materials can be used for concrete structures can even replace reinforcing steel that has been widely used in building construction in Indonesia.**

Key words—**CFRP material, concrete structure, increase strength.**

I. Introduction

Technological developments, especially the rapidly growing field of materials characterized by the appearance of materials such as FRP Composite. For building construction such as bridges or buildings previously used material of bamboo, wood, and steel that serves as reinforcement. However, the material for structural applications is updated by an expert building or construction material in the world along with the emergence of the material weakness. Bamboo materials such as those used for the construction proved to have some drawbacks, such as bamboo has a very low resistance, so the potential for bamboo powder beetles attacked, so the buildings are made of durable bamboo. Therefore the order of the building from bamboo that is not preserved only seen as a temporary building components simply do not hold more than 5 years.

For wood materials are also widely used for the construction of houses, offices, and bridges in particular in the village, but this material was also proved to have weaknesses. The disadvantage is extremely flammable, can be eaten by termites, may expand and creep, stretch for apps roof with wood construction is often limited due to the size of the timber on the market is only about 4 meters, and other weaknesses in terms of procurement, then in the long run the price of wood are increasingly expensive because of the decreasing availability of natural wood materials. Other materials such as concrete have been widely used in Indonesia, but it also had shortcomings in terms of usage for construction. Weaknesses were found among forms that have made it difficult to change, the weak against the strong pull, has a heavy weight, great sound reflections power, and execution of work requiring high accuracy.

Meanwhile, the material of the steel used for the construction of buildings is still relatively large and very dominant utilized in Indonesia to date. This material has many advantages such as high tensile strength, not eaten by termites, able to carry a heavy burden, resistant to high temperatures, low maintenance costs, and easily molded according to the needs of the construction. However, it turns out, according to experts looking at the field of construction materials still have a shortage of them can be rusty, weak against the compressive force, not as flexible as wood can be cut and shaped a variety of profiles, not solid, and not resistant to fire, and in the case of slender structures harmless against buckling. Therefore, the various shortcomings of the steel material and other materials such as bamboo, wood, and concrete. So the development of civil engineering construction material appears more promising and superior to other materials that CFRP material. Superiority in terms of stress and strain in the CFRP material compared to other materials can be seen in Figure 1 below (Tamon U, 2004)

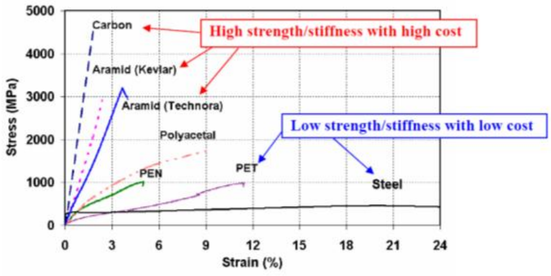

Figure 1. Strength/stiffness and fracturing strain relationship

For the construction of the developing world of technology in the field of civil engineering materials and structural systems running very fast. This is demonstrated by the increasing proliferation of research and discoveries are oriented to the use of high performance materials coupled with the structure of the research system, the better. The combination of the use of high-performance materials in structural components is reasonable and in certain circumstances can not be avoided anymore. These conditions, among others, due to the demands of mechanical performance, durability, ease of construction, environmental and economic aspects. Application of CFRP materials can function as a repair and strengthening of concrete structures. Retrofitting with CFRP system function can improve strength and provide increased flexural capacity, shear, axial, and ductility. CFRP materials for building construction has many advantages, including high durability CFRP and more economical use in corrosive environments than are easily corroded steel material.

The use of CFRP is more popular considering the number of benefits that can be obtained as the weight of the unit is a small, easy to apply and are handled, the cost of installation and low maintenance. Material can provide the most economical solution in retrofitting problem because it can dramatically reduce the cost of labor. CFRP can be used to increase the bending and shear capacity of reinforced concrete beams, bending plate, push, shear and flexural column. CFRP in the form of sheet, plate or bar can be mounted on the surface of the beam or plate having a stretch as a flexure reinforcement. As the beam shear reinforcement, CFRP sheets can be glued to the side of the beam. Usage on columns, CFRP sheets can be placed on the outside of the column to increase the ductility and strength.

CFRP material that can stick to the structural elements such as beams, columns, plates, then given the adhesive epoxy resin has the basic ingredients. This adhesive is made from a mixture of two components. Its main component is an organic liquid that is loaded into the epoxy, binding arrangement or oxygen atoms and two carbon atoms. Was added to the reaction mixture to obtain the final mix. The surface to be attached should be prepared to obtain an effective juxtaposition including cleanup efforts on the surface of the structural element to be attached to the CFRP materials are free from contaminants oxide, oil, grease, and dust.

In this research, testing the strength of the CFRP material serves as reinforcement in concrete columns. The columns were tested circular column with a diameter of 130 mm and length is 700 mm column. The focus of research is directed at improving the lateral voltage such that it adds strength, slow collapse process as well as a wide cross-section of the column is ductile collapse. The results of this study, results in a significant force in the column. This suggests that the use of CFRP materials can be used as a function of reinforcement and become an alternative to steel reinforcement that has been most widely used in building construction in Indonesia.

II. LITERATURE REVIEW

A. Research results of CFRP materials for Construction

Elnabelsy G and M Saatciouglu conduct research related to the improvement in the round concrete columns designed with FRP materials in 2004 in Canada. They perform tests of three large-scale bridge columns are reported in this paper. All columns had a 508 mm circular cross-section and were designed to have predominantly flexural response with a shear span of 2.0 m Measured to the point of application of load, Consisting of 1.7 m of concrete column height and 0.3m of top loading beam height. They were reinforced with 12 - 19.6 mm diameter, 400 MPa grade deformed reinforcement, Equally distributed along the section perimeter. Each bar was spliced near the base with a splice length of 390 mm, corresponding to 20 times the bar diameter. Each column had a diameter of 11.3 mm deformed transverse reinforcement, spaced at 300 mm in the form of circular hoops with overlapping ends. The first column tested (BR-C8) was the reference column reflecting as-built conditions, without any seismic retrofit. The companion two columns were retrofitted with MBrace CF 130 carbon fiber sheets. Column BR-C8-1 had four plies of CFRP sheets, whereas Column BR-C8-2 had two plies wrapped around the column. The surface of columns was first treated with an epoxy-based primer. The CFRP sheets were pre-cut to the required length and applied on columns with epoxy saturant. Coupons were made from CFRP jacket and tested to establish the actual stress-strain relationship of composite materials. Accordingly, the jackets had approximately 60,000 MPa elastic modulus and ultimate strength of 700 MPa, with linear elastic behavior. From these tests yield data shown in Figure 2, 3, and 4.

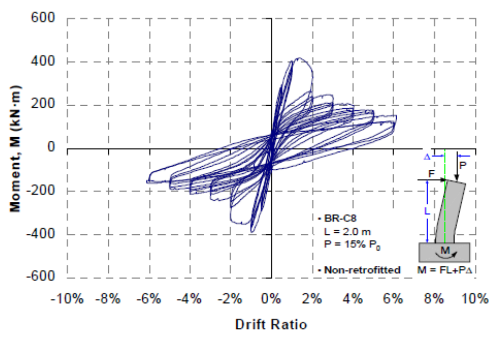

Figure 2. Reference column (non-retrofitted) BR–C8,

reflecting as built conditions

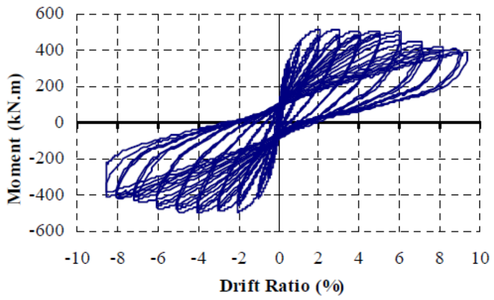

Figure 3. Column BR-C8-1, retrofitted with 4 plies of CFRP sheets

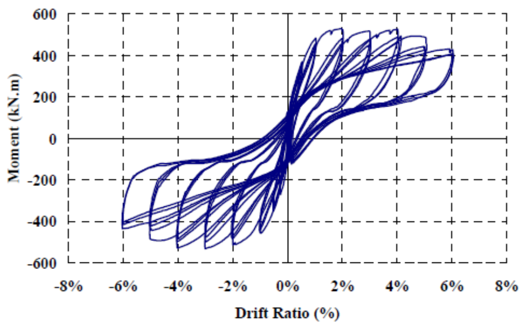

Figure 5 Experimental stress-strain curves for Toronto specimens

By looking at figure 2, 3, and 4 can be reported that the Columns with spliced longitudinal reinforcement in their potential plastic hinge regions near the base have limited drift capacity. The circular column tested in this investigation developed lateral drift ratio of 1% prior to significant decay strength. The failure resulted from slippage of spliced reinforcement. Then, the circular columns retrofitted with CFRP sheets Showed Significantly improved hysteretic behavior. Hoop tensioned developed in the CFRP jacket maintained the bond between reinforcement and concrete in the splice region. The column with four plies of CFRP sheets (jacket thickness of 3.6 mm) was Able to sustain in excess of 6% lateral drift ratio without significant decay strength. The companion column with two plies of sheets (jacket thickness of 1.8 mm) Showed 4% to 5% drift ratio with pinched hysteresis loops.

Benzaid R and Mesbah AH also conduct research investigations on round and rectangular concrete columns of CFRP externally supplied. The experimental program was carried out shorts column specimens with a square cross section of 140x140 mm and a height of 280 mm. For all RC specimens the diameter of the longitudinal and transverse reinforcing steel bars were respectively 12 mm and 8 mm. The longitudinal steel ratio was constant for all specimens of 2.25% and equal to .The yield strength of the longitudinal and transverse reinforcement was 500 MPa and 235 MPa, respectively.

The results of this investigation reported that in all cases the presence of external CFRP jackets Increased the mechanical properties of PC and RC specimens, in different amount According to the number of composite layers, the concrete properties and the cross-section shape. thus the use of Carbon Fiber Reinforced Polymer is an efficient means of providing confinement of concrete for strength and ductility enhancement.

Samdani S and AS Sheikh also conduct research related to concrete columns given CFRP confinement. Twenty-eight nearly full-scale concrete columns were tested under monotonic concentric load at the University of Toronto. The variables tested in the experimental study included the type of FRP (glass or carbon), the number of layers of FRP, the orientation of fibers in the FRP shell and the amount of lateral reinforcement. All specimens were 356 mm in diameter, 1524 mm high standing. The response of the concrete confined with FRP Showed two slopes of the ascending branch before the peak stress. The first slope was approximately equal to that of unconfined concrete. The second slope, being less steep, started near the peak stress of the unconfined concrete and continued until the peak. This was Followed by a significant post-peak response that continued until the FRP shell was sufficiently ruptured, resulting in a sudden drop of stress in concrete. Figure 5 shows the axial stress-axial strain curves for some of Toronto specimens, confined with 1 and 2 layers of CFRP and GFRP.

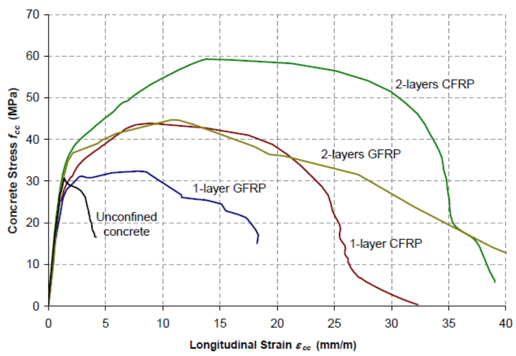

Figure 4 Column BR-C8-2, retrofitted with 2 plies of CFRP sheets

From figure 5 we see that the concrete was not given CFRP and GFRP rebars was experiencing rapid collapse. However, if given the CFRP and GFRP materials externally, the stress and strain increased significantly from concrete without reinforcement of CFRP and GFRP. If given 2 layers of CFRP and GFRP then continue to experience an increase of 1 layer of CFRP and GFRP rebars. The incidence of laboratory results indicate that given the additional CFRP layers, the more stress and strain increased.

Ongpeng CMJ doing research for improvement in the column using CFRP materials in 2006 in Manila. In his study, ninety four specimens of sizes 180mm diameter by 500mm height were fabricated and tested. This means fully wrapped CFRP specimens were used with the unconfined compressive strength of 30 MPa, 120 mm spacing for the steel ties, using two plies of CFRP, and the first specimens out of a total of three identical specimens. In wrapping CFRP to the concrete specimens cured for 28 days, the fibers were oriented 90 ° with respect to the longitudinal axis of the concrete column. In the preparation of the epoxy matrix, the resin and hardener

ratio is 4: 1 and was hand mixed for at least 5 minutes. The overlap of CFRP is 35 mm and 70 mm for the one-and two-layer of CFRP respectively.
The results of this study can be seen in Figure 6 the stress-strain diagrams of the three specimens that have no steel ties and 40-mm spacing of steel ties, respectively, with increasing amount of CFRP ply used from zero to two plies. It can be observed that the confinement effect of using CFRP and steel ties had Increased the compressive strength and the average longitudinal strain Represents that the ductility of the specimen.

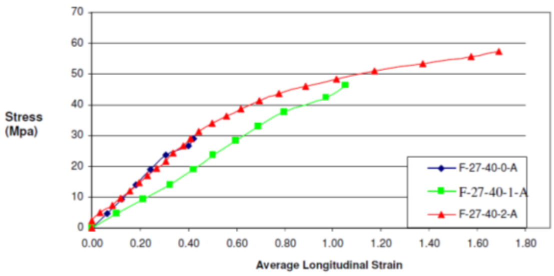

Figure 7 Stress-Strain diagram of specimens with steel ties

Furthermore, Ongpeng CMJ and Oreta CW also conducted research on the effect of CFRP on restraints on a column by using Artificial Neural Networks. In this study, there are three sets of the data collected from references. It was Categorized as follows: SC (Steel Confinement) data sets that steel ties used alone as confining material, CC (CFRP Confinement) set - that the data used alone as confining CFRP material, and SCC (Steel and /or CFRP Confinement) data sets that used both, steel ties and /or CFRP, as confining materials.

From these results, it was found the effect of CFRP on concrete columns. Effect of CFRP materials can be seen in the image below. Figures 8 and 9 that there is an abrupt increase is of at least 65% to 100% in f'cc from zero-ply to one-ply of CFRP Regardless of the spacing of lateral steel ties. However, by adding another ply of CFRP to a total of two plies, the increase of was minimal. One common geometric property between the column by Mander et al 1988b Hoshikuma et al 1997 and is the outer diameter D. Both columns have are relatively large outer diameter D = 500mm for both, and the core diameter, d = 438 mm and d = 500 mm respectively .

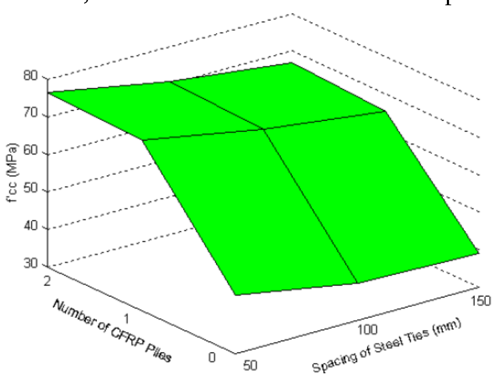

Figure 8. Mander et al 1988b with addition of CFRP sheets as confinement (D=500mm, d=438mm, L=1500mm, ρ_{cc}=1.6%, fys=340Mpa, lateral steel bar diameter=12mm, and f'c=28 Mpa)

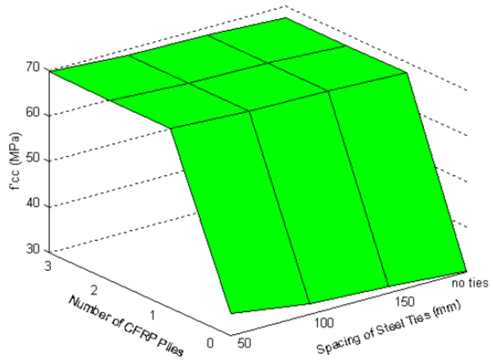

Figure 9. Hoshikuma 1997 with addition of CFRP sheets as confinement (D=500mm, d=500mm, L=1500mm, ρ_{cc}=1.01%, fys=295Mpa, and f'c=28.8 Mpa)

In figure 10. using closer tie spacing, which results to an increase in ρs, led to a gradual increase in *f'cc*. On the other hand, increasing the over-all thickness of the CFRP by varying the number of CFRP ply also shows significant enhancement of compressive strength. Except for the RC column having no steel ties, an addition of 1-ply led to no increase in f'cc.

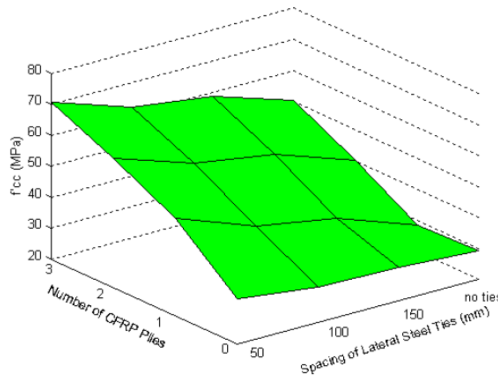

Figure 10. Sakai et al 2000 with addition of CFRP sheets as confinement (D=200mm, d=185mm, L=600mm, ρ_{cc}=1.18%, fys=376Mpa, and f'c=29.8 Mpa)

In figure 11 can be seen throughh enhancement due to superposition effect of each material are less than that of the actual experimental data for 1-ply and 2-plies of CFRP. On the other hand, the ANN model SCC9-7-1B, which assumed no superposition of strength enhancement on each confining materials, but rather the total enhancement due to the interaction of both.

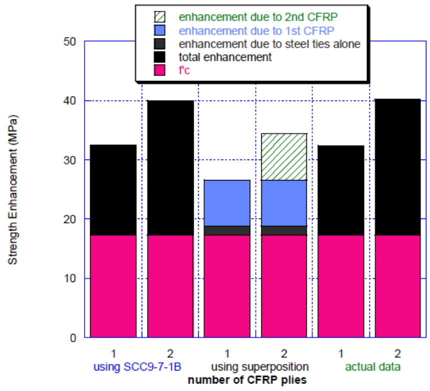

Figure 11. Strength Enhancement using Li and Fang 2004 Data (D=300mm, d=250mm, L=600mm, $\rho s = 1.41\%$, ρcc=0.76%, fyh=274.7Mpa, t=0.11mm, fyfrp=4120.2Mpa, fc'=17.2Mpa)

B. Application of CFRP in the construction

In research Hota G and Liang R in 2011 relating to the use of CFRP Civil Infrastructures. This study is an example of CFRP retrofitting has been Widely used successfully to Strengthen the structures as an effective disaster prevention approach or to restore the damaged structures after disasters such as hurricanes and Earthquakes. In the United States, many of the existing highway or railroad bridges have either reached the end of Reviews their service life or require rehabilitation to continue in service. Due to Decreased funding levels for new constructions, government agencies are interested in utilizing FRP wraps to rehabilitate structures at a fraction of the outright replacement cost and extend the structural service life for few more decades. The advantages of CFRP wraps include a minimum of traffic disruption, efficient labor utilization, ease of rehabilitation, optimization of load transfer, and cost effectiveness. CFC-WVU laboratory has been actively involved with FRP wrapping advanced technology development, Including specific design methods, material selection, field installation procedures, performance requirements and subsequent inspection techniques.

Figure 12 is a group of photos showing how damaged piles of 11 timber railroad bridges on South Branch Valley Railroad (SBVR) lines in Moorefield, WV were rapidly rehabilitated and restored in-situ without affecting the rail traffic, with the use of Fiber Reinforced Polymer (FRP) composites (July 2010). These timber bridges consisted of total span lengths varying from 75 ft. to 1200 ft. with timber pile bents spaced 15-20 ft apart. The deteriorated piles were cracked, heart-rotted, and damaged to varying lengths. This rapid rehabilitation technique can be used on various other structural members including steel and reinforced concrete members in a highly cost effective manner to extend the service life of structural systems.

Figure 12. Retrofitting of railroad bridges using FRP wraps, SBVR, Moorefield, WV (July 2010)

Furthermore, much of the existing building stock in Europe, as well as in developing countries, has been designed According to old standards and has little or no seismic provision and Often suffers from poor materials and construction practices. As a result, many existing buildings have deficient lateral load resistance, insufficient energy dissipation and can Rapidly lose during Earthquakes Reviews their strength, leading to collapse. Retrofit of seismically deficient structures before Earthquakes provides a feasible and cost-effective approach to improving Reviews their load carrying capacity and reducing Reviews their vulnerability. Over the last decade, the use of externally bonded fiber composite materials (FRPs) has offered engineers a new solution for strengthening seismically deficient buildings (Figure 13). The initial cost of FRP for strengthening is usually higher than conventional structural materials. However, they are much Easier to apply, and this is where composites offer significant economic benefits.

Figure 13. Strengthening of a RC columns with FRPs

III. RESEARCH MODEL

In this article the authors also present the results of research on the use of CFRP materials are applied to the round concrete columns that serve as external reinforcement in concrete columns. The work is done through analysis and experimental studies. The study analysis was conducted to study the stress strain models that utilize concrete as a material CFRP reinforcement in concrete columns.

Models stress strain of CFRP material is then summarized and implemented in the form of a computer program Confined Column v.1.0 (CC-v.1.0) that have been made to produce a stress strain relationship chart. The program is used to validate the results of experimental studies.

In this study the implementation of the test specimen used in the column that is round with a diameter of 130 mm diameter by 700 mm long round columns. In this study conducted experiments on plain concrete columns (PS), which uses concrete columns internally reinforced steel (BT), and given a plain concrete column steel reinforcement internally and externally CFRP material (B-1 LS). Concrete used is normal strength concrete with a target compressive strength of 20.75 MPa. For longitudinal reinforcing steel used 6 Ø 10 and ridden spiral reinforcement is Ø 8-50 mm. Furthermore, an analysis and evaluation of the results of testing that has been done to study the behavior of restrained concrete columns with fiber polymer (CFRP) as well as models of effective restraint. In addition, we will get the formulation / formulas stress strain constitutive relations that occur due to the confined of the fiber polymer (CFRP). The resulting formulation results will be validated using the constitutive equations of the results of other researchers with the help of Confined Column v.1.0 program (CC-v.1.0) that have been made.

IV. RESULT AND DISCUSSION

Model collapse on circular concrete columns after testing in the laboratory can be seen in figure 13 below.

(a) PS (b) B T (c) B-1LS

Figure 13. Collapse of Specimen Model PS, BT, and B-1 LS

Based on laboratory test results obtained from the maximum load of each variation of the concrete columns were tested, as shown in Table 1 in the column of concrete without confinement (PS), concrete columns with transverse reinforcement confinement and longitudinal reinforcement (BT), and concrete columns with confinement transverse and longitudinal steel reinforcement and external confinement with CFRP 1 (one) layer spacing (B-1 LS). In Table 1 are shown the maximum load difference of different variations of the test specimen.

TABLE 1. RESULTS OF TESTS ON CIRCULAR COLUMN

No	Specimen Code	Maximum Load (kN)	Maximum Load Average (kN)	Increased Maximum Load (%)
1	PS-A	150	150	-
2	PS-B	140		
3	PS-C	160		
4	BT-A	230	240	60
5	BT-B	250		
6	BT-C	240		
7	B-1 LS-A	280	270	80
8	B-1 LS-B	270		
9	B-1 LS-C	260		

Source: Research Results

Based on the research that has been summarized in Table 1 show that the concrete column specimen without restraint (PS) capable of withstanding a load of 150 kN, while the concrete columns with transverse reinforcement confinement and longitudinal reinforcement (BT) is able to withstand a load of 240 kN, and the concrete columns with transverse reinforcement confinement and longitudinal reinforcement as well as externally with CFRPconfinement (B-1 LS) capable of withstanding a load of 270 kN. This suggests that an increase in the strength of the concrete column specimen BT by 60% when compared to columns that are not confined, while the test specimen B-1 LS increase is as high as 80% when compared to the concrete columns that are not confined. It shows that the functioning of the confinement of transverse and longitudinal steel reinforcement and confinement externally with the use of CFRP materials.

Stress strain curves for all test objects can be seen in Figure 14 as the comparative column specimens studied. Concrete column specimens were observed without the use of confinement, and concrete columns using CFRP restraint. In figure 14 it can be seen that the presence of transverse and longitudinal reinforcement (Specimen BT) can improve axial compressive stress. The most influence on the value of confinement is the specimen B-1 LS because in addition to using the transverse and longitudinal reinforcement, also using CFRP material as an external confinement. Increased confinement posed CFRP compared to concrete specimen (BT) is 12.5%. The results showed that with the use of CFRP materials as an external confinement can increase the capacity of the concrete column. It is appropriate that disclosed by Mac Gregor (1997) which states loading triaxial strength of concrete with concrete (confinement) is greater than the compressive uniaxial loading.

A. *Validation of Experimental Results*

Validation of Value Unconfined Concrete Strength

The result of the increase in strength of confined concrete validation (K) to review the model formulation by previous researchers using triaxial test results can be seen in Table 2. The model being simulated is a model of Campione and

Miragle (2003), the model of Li et al (2003), and the model of Lam and Eng (2003).

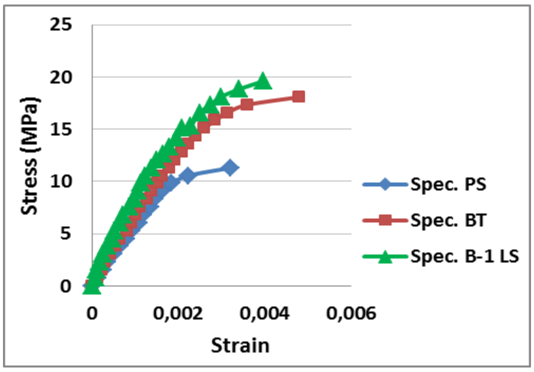

Figure 14. Stress strain curve of specimens

Formulation of the model equations are then processed to determine predicted for confined concrete strength (K) as a validation of the experimental results of short column testing (short column) with CFRP confined concrete is given a concentric load. Validation is performed to determine the accuracy of each equation in predicting an increase in confined concrete strength (K) based on the experimental results. All three models are reviewed each have a value of COV (Coefficient of Variation) above 9%. Among the three models is the model of Lam and Teng have COV higher value, is 10.71%, which means closer to the experimental results with a 11.13% COV value. Meanwhile, the model of Li et al have COV values of 10:07%, and The Campione and Miragle model has the value COV of 9.27% of the experimental results. All three models are reviewed indicates that predicted for confined concrete strength (K) to the experimental results are considered quite good because it has the value COV proximity to the experimental results.

TABEL 2. COV VALUE OF PREDICTION RESULT VS EXPERIMENTAL RESULT

Model	**COV (%) for** $(K = \frac{f'_{cc}}{f'_{co}})$
Campione and Miragle (2003)	9.27 %
Li et al (2003)	10.07 %
Lam and Teng (2003)	10.71 %
Experimental Result	11.13 %

Source: Analysis Results

Curve model validation of stress-strain unconfined concrete for experimental results

Stress strain curve modeling confined concrete (confined concrete) transverse and longitudinal reinforcement and externally CFRP layers are calculated based on the results of experiments on 9 test specimens in the form of columns of normal strength concrete (NSC), and tested with concentric loading. Proposed stress strain curve is given one part based on the results of laboratory testing through system testing using Load Control technique with the speed of movement (stroke) of 0.012 mm / sec. The results of testing this model produces a stress strain curve the shape of the ascending branch. The resulting model is then summarized and carefully observed the movement of the model curve shape of the experimental results. The resulting shape of the curve in general form a parabolic curve with peak coordinates $(f'_{cc}, \varepsilon_{cc})$. The results of the model formulation of the stress strain curve of the experimental results with comparison of some models of previous investigators are shown in Table 3, while, for the model of confined concrete stress strain curve of the experimental results with two models, namely the model in terms of Li et al (2003) and Model Campione and Miragle (2003) is shown in figure 15.

TABLE 3. CURVE MODEL OF STRESS STRAIN FOR CONFINED CONCRETE

Researchers	**Curve Model of Stress Strain for Confined Concrete**	
	Ascending Branch	**Descending branch**
Lam and Teng Model (2003)	$f_c = E_c\varepsilon_c - \frac{(E_c - E_2)^2}{4f_{co}}\varepsilon_c^2$	$f_c = f_{oc} + E_2\varepsilon_c$
Model Li et al (2003)	$f'_c = f'_{cmax}\left[2\frac{\varepsilon_c}{\varepsilon_{cmax}} - \left(\frac{\varepsilon_c}{\varepsilon_{cmax}}\right)^2\right]$	$f_c = f_{cmax} - E_{des}(\varepsilon_c - \varepsilon_{cmax})$
Campione and Miragle Model (2003)	$\frac{f_c}{f'_{co}} = \frac{E_2}{E_1}.\frac{\varepsilon_c}{\varepsilon_{co}} + \frac{\left(1 - \frac{E_2}{E_1}\right).\frac{\varepsilon_c}{\varepsilon_{co}}}{\left[1 + \left(\frac{\varepsilon_c}{\varepsilon'_{co}}\right)^{n'}\right]^{\frac{1}{n'}}}$	
Proposed Model Experimental Result	$f_c = 10193(\varepsilon_c - 136.4\varepsilon_c^2)$	

Source: Research Result of Lam and Teng, Li et al, and Campione and Miragle Model

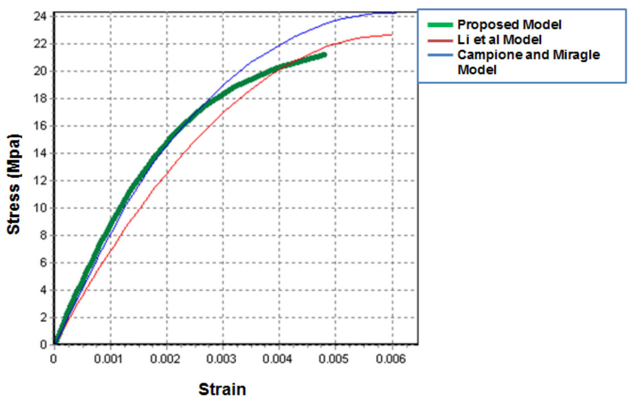

Figure 15. Proposed Model of Confined Stress Strain Curve with Li et al, and Campione and Miragle Model

V. CONCLUSION

Based on the results of experimental studies that have been done, it can be concluded as follows:

- Calculation results of experiments on the effectiveness of the confinement of a plain column (PS), reinforced column (BT), as well as external confinement CFRP reinforced column (B-1 LS) with a COV value of 11:13% is considered good enough to see the result of validation of the value of K generated by Lam and Teng model, Li et al model, and Campione and Miragle model and the experimental result which each have a COV value of 10.71%, 10:07%, and 9:27%.
- The capacity of strength that occurred in plain concrete column (PS) is 150 kN. If given additional concrete column internally reinforced steel, the strength increased capacity is 240 kN. Effect capacity is the greatest force if given the confinement of steel concrete columns internally with CFRP material externally is equal to 270 kN. Thus, the addition of transverse and longitudinal reinforcement confinement (BT) has increased the strength by 60% when compared with plain column without confinement (PS), and an increase in capacity of the column concrete were confined by transverse and longitudinal reinforcement (BT) to concrete column were confined with transverse and longitudinal reinforcement or external confinement 1 layer CFRP spacing (B-1 LS) of 12.5%. With the results of these experiment that utilize CFRP material as an external confinement can provide increased strength to the concrete column and can be an alternative material for building construction and other building as reinforcement.
- Model of constitutive formulation proposed for stress strain can predict the stress strain curve of CFRP confined to the accuracy of the model is not much different from the model of Li et al, as well as the Miragle and Campione model.

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