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GFRP Material as External Reinforcement for RC Column Bridge

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Abstract: The column is an important structural component for supporting axial load, bending moment and shear force. Damage caused by shear failure is seen as the most dangerous because the damage can cause structural collapse suddenly. Therefore, the columns of a building that has inadequate shear strength, so that, needs to be strengthened with appropriate methods. One method that is appropriate to maintain the stability of structural elements of the column is a strengthening. In this study, the materials to be used as a strengthening of the GFRP material therefore has a a high tensile strength light weight and it's easy in implementation. The method used in this study is a method of strengthening with Glass Fiber Reinforced Polymer (GFRP) with model testing of concentric loading. In this study, the specimen will be used 9 specimens of the circular columns with models of variation is 3 specimens of RC circular columns without the use of GFRP, 3 specimens of RC circular columns, 3 specimens of RC circular columns with 1 layers of Glass fiber Reinforced Polymer (GFRP) and 3 specimens of RC circular columns with 2 layers of Glass fiber Reinforced Polymer (GFRP). The circular column with a diameter of 130, height 700 mm with reinforcement longitudinal 6Ø10 and spiral reinforcement for the transverse reinforcement is Ø 8-50 mm. The experimental results show an increase in the capacity of a circular column to one GFRP layer happen a increasing the strength of 12.17% if it's compared with no use of GFRP material and the circular column capacity of 1 GFRP layer to 2 GFRP layers have a increasing the strength of 8.53%

Key words: GFRP, circular column, strength increase, axial strengthening, layers, columns

INTRODUCTION

In recent years, materials for building construction have grown rapidly which experienced rapid development is a fiber material, known as Fiber Reinforced Polymer (FRP). FRP of various kinds, namely carbon, glass and aramid. The use of Glass Fiber Reinforced Polymer GFRP has been widely applied to many types of buildings including for high rise buildings and bridges used in damaged structural elements such as beams and columns and other structural elements as models for strengthening the structure.

In the case of building structures, column elements often fail because of misstatements in the planning or cost of destructive earth quake construction. The presence of Glass Fiber Reinforced Polymer (GFRP) materials in building construction is seen as a material capable of withstanding tensile strength, improving and increasing structural strength in concrete columns. Therefore, Glass Fiber Reinforced Polymer (GFRP) has a tensile strength that is much higher than the tensile strength of steel reinforcement.

Therefore, to avoid failure of column elements focused on bridge columns, it will be reinforced with Glass Fiber Reinforced Polymer (GFRP) to maintain structural stability and prevent sudden collapse. Strengthening of bridge columns by using exterior jacketing method Glass Fiber Reinforced Polymer (GFRP) is one of the alternatives that can be done to increase the strength of columns on the bridge.

In a study conducted by some previous researchers proved to be quite effective, it can increase the axial capacity of the bridge column. Through this concept, the researcher studied more deeply about the possibility of a significant increase when the use of Glass Fiber Reinforced Polymer (GFRP) was applied to the bridge column and how big the increase in strength. With laboratory studies and applying the Glass Fiber Reinforced Polymer (GFRP) external reinforcement method is expected to increase column strength. Based on what has been described, it is necessary to learn to know the behavior of certain layers of bridge columns using Glass Fiber Reinforced Polymer (GFRP) materials as external confinement to increase their strength and ductility value.

Research on column components has been largely done in recent years, especially in the case of the use of FRP as a transversal reinforcement for column restraints for external restraints on columns. Some studies using carbon fiber (FRP) as a restraint in the column resulting in a restraint formula with FRP can create effective confinement, adding strength and ductility to the column (Bisby *et al*., 2005; Toutanji *et al*., 2010).

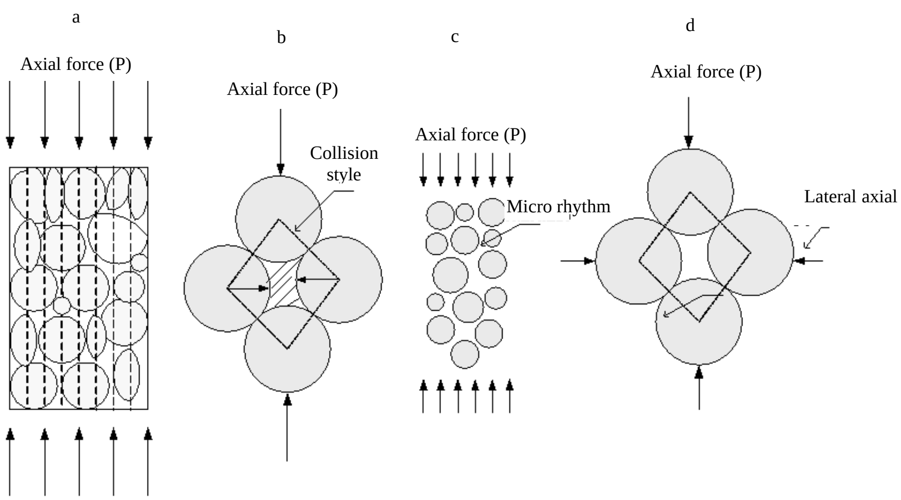

Fig. 1: The mechanism of restraint of concrete (CEB-FIP, 1990): a) Path Forces that act on aggregates; b) Transmission of forces from particles to particles; c) Interfacial cracks due to uniaxial loads and d) Effects of restraints

Literature review

Confinement of concrete structures: The most common confinement is restraint using steel-reinforced bars. This type of confinement is known as passive confinement. The passive confinement model has a different behavior than active restraint. Passive impedance is in the form of confinement by lateral reinforcement in both spiral and square shapes and active confinement in which the strain may be provided by the fluid.

In passive constraints, the lateral pressures given are not constant like active strain but depend on the axial deformation of the concrete core and the lateral reinforcement characteristic behavior. In addition, the restraints afforded by the lateral reinforcement will result in an uneven, lateral force acting on the concrete core, the lateral rebound tension, the spacing and the lateral reinforcement configuration.

While active restraints provided by the fluid will produce a uniform lateral force on the entire surface of the concrete. In relation to this if the concrete is curbed in all or part of its direction then the behavior of strength and ductility will increase significantly and the collapse is not brittle. While, unconstrained concrete with uniaxial press load has a brittle collapse behavior. In the application of restraints on concrete, the boundary conditions greatly affect the mechanical behavior of concrete. The availability of such boundary conditions may result in restraint of the tendency of the material to deform laterally due to the loading it undergoes.

The pattern of concrete collapse due to uniaxial load is generally characterized by the uncontrolled volume (volume expansion). The presence of a restraint mechanism working on the concrete causes the collapse process to occur to be slowed or controlled. One of the mechanisms of the resistance is the lateral reinforcement. The mechanism of the occurrence of restraints in the concrete in detail can be seen in Fig. 1. The axial force of P press acting on the surface of the concrete will be continued to the concrete aggregate (Fig. 1a), resulting in collisions or aggregate friction (Fig. 1b). Micro cracks will propagate rapidly then macro cracks will occur until the concrete collapses. The process of collapse of the concrete can be slowed down when there is a lateral force that serves as a confinement that is.

Confinement with FRP: Along with the development of restraint research using FRP, the parameter f'l (stress curve) for the FRP case is different from the restraints using conventional reinforcement. The comparative illustration of the use of the material is shown in Fig. 2.

Campione and Miragle (2003) proposed an improved strength formulation due to FRP confinement:

$$f'_{cmax} = f'_{co} + 2.fl \tag{1}$$

While the strain at the peak stress of the concrete cross section is:

$$\varepsilon'_{cmax} = \frac{8_{nFRP}}{D} \frac{f_{FRP^2}}{E_{frp}} \frac{1}{f'_{co} + fl}$$

$$f_c = f_{cu} - \lambda \left(\varepsilon_{cu} - \varepsilon_c\right) \tag{2}$$

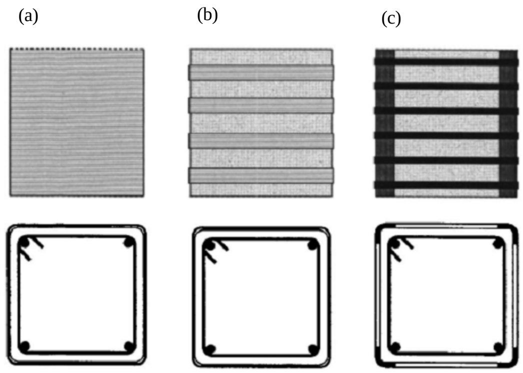

Fig. 2: a, b) Confinement with FRP jaket and c) Conventional confinement

Lam and Teng (2003) proposed the addition of strength due to confinement with FRP are:

$$f'_{cmax} = f'_{co} + 3.3 \frac{f_{l,w}}{f'_{co}} \tag{3}$$

With strain of:

$$\frac{\varepsilon'_{cmax}}{\varepsilon'_{co}} = 1.72512 \left(\frac{f_{l,w}}{f'_{co}}\right)\left(\frac{\varepsilon_{F,w}}{\varepsilon'_{co}}\right)^{0.45} \tag{4}$$

Furthermore, the constitutive equation for ascending branch, region 1 is:

$$f_c = E_c\, \varepsilon_c - \frac{(E_c - E_2)^2}{4\, f_{oc}}\, \varepsilon_c^2 \tag{5}$$

Whereas in the constitutive equation of region 2 is:

$$f_c = f_{oc} + E_2\, \varepsilon_c \tag{6}$$

With:

$$E_2 = \frac{f'_{cmax} - f_{oc}}{\varepsilon'_{cmax}} \tag{7}$$

While the strain at the peak stress is equal to:

$$\frac{\varepsilon'_{cmax}}{\varepsilon'_{co}} = 1.75 + 12 \left(\frac{f_{l,w}}{f'_{co}}\right)\left(\frac{\varepsilon_{E,w}}{\varepsilon'_{co}}\right)^{0.45} \tag{8}$$

Li *et al*. (2005) propose a peak axial stress expressed as follows:

$$f'_{cmax} = f'_{co} + f_{i\,tan^2}\left(45° + \frac{\varphi}{2}\right) \tag{9}$$

With the proposed strain:

$$\varepsilon'_{cmax} = \varepsilon'_{co}\left[1 + 2.24 \tan^2\left(45° + \frac{\varphi}{2}\right)\frac{f_l}{f'_{co}}\right] \tag{10}$$

Furthermore, the constitutive equation for the ascending branch I:

$$f_c = f'_{cmax}\left[2\frac{\varepsilon_c}{\varepsilon'_{cmax}} - \left(\frac{\varepsilon_c}{\varepsilon'_{cmax}}\right)^2\right] s \tag{11}$$

While in the descending region or region to-2 (descending branch, region 2 is:

$$f_c = f'_{cmax} - E_{des}\left(\varepsilon_c - \varepsilon'_{cmax}\right) \tag{12}$$

And ultimate strain is calculated as:

$$\varepsilon'_{cu} = \varepsilon'_{cu} + \frac{f'_{cmax}}{2\, E_{des}} \tag{13}$$

MATERIALS AND METHODS

In this study, an analytical and experimental study was conducted. An analysis study was conducted to study concrete column strength models that existed in the literature and then reviewed several design parameters that influenced the behavior of the strength of the main confined concrete columns that were confined with Glass Fiber Reinforced Polyemer (GFRP). Confined concrete column models are then summarized and then implemented in the form of a confined column V.1.0 (CC-V.1.0) computer program that has been created to generate a stress strain relationship graph. The program is used to validate the results of experimental studies.

In the implementation of this study used a test object in the form of a column with a circular study with a short column category with a diameter of 130 mm with a circular column length of 700 mm. The experiment consisted of 3 variations of test specimens, concrete columns with internal reinforcing steel (CR), Columns of concrete with internal reinforcing steel and 1 layer external GFRP (CR-1L) and concrete columns with internal reinforcing steel and 2-layer external GFRP (CR-2L). The material used as external confinement is the material of Glass Fiber Reinforced Polymer (GFRP) whereas the concrete used is a normal quality concrete with a compressive strength target of 20.75 MPa. For longitudinal reinforcing steel used 6Ø10 and spiral reinforcement is Ø 8-50 mm.

Furthermore, an analysis and evaluation of the results of the tests has been conducted to determine the behavior of concrete columns that are confined with Glass Fiber Reinforced Polymer (GFRP) as well as an effective confinement model. In addition, there will be a formulation of the constitutive relationship of stress strain that occurs due to the Glass Fiber Reinforced Polymer (GFRP). The result of the formulation will be validated by using constitutive equation from the result of other researchers with the help of confined column v.1.0 (CC-v.1.0) program that has been made.

RESULTS AND DISCUSSION

Based on the results of laboratory tests obtained the maximum load of each tested concrete column variation as shown in Table 1 on concrete columns with internal reinforcing steel (CR), Columns of concrete with internal reinforcing steel and 1 layer external GFRP (CR-1L) and concrete columns with internal reinforcing steel and 2 layer external GFRP (CR-2L). In Table 1 this shows the maximum load difference of the various test specimens.

Based on research results are summarized in Table 1 show that the concrete column with specimens using internal reinforcing steel (CR) is able to withstand the load of 230 kN while columns of concrete with internal reinforcing steel and 1 layer external GFRP (CR-1L), capable with loads of 258 kN and concrete columns with internal reinforcing steel and 2-layer external GFRP (CR-2L) able to withstand loads of 280 kN. This result shows that the strength of concrete column of CR-1L specimen is 12.17% when compared with concrete column which only use internal reinforcement steel, while CR-2L specimen has very high increase 21.74% compared to concrete column only using internal reinforcement steel. This indicates that the increasingly functioning confinement external utilizing the Glass Fiber Reinforced Polymer (GFRP) material.

Table 1: Results of circular column testing

Specimen code	Maximum load (kN)	Average maximum load (kN)	Enhancement maximum load (%)
CR-A	220	230	-
CR-B	240	-	-
CR-C	230	-	-
CR-1L-A	250	258	12.17
CR-1L-B	260	-	-
CR-1L-C	265	-	-
CR-2L-A	275	280	21.74
CR-2L-B	280	-	-
CR-2L-C	285	-	-

Model of specimen collapse

Columns without confinement (PC): Observation for the collapse of the specimen without confinement (PC), shown the occurrence of fine cracks on the surface of the test specimen and when the load is increased the crack is widened and the concrete blanket is released as the load approaches the maximum load and when it reaches the peak load there is rapid collapse. The collapse model of the specimen without the use of transversal reinforcement and longitudinal reinforcement as well as CFRP material is categorized as spilitting failure is a pattern of crack parallel to the longitudinal axis of the specimen. This type of collapse model is shown in Fig. 3a.

Columns with internal reinforcing steel Confinement (RC): The collapse of a RC type object is marked by the loss of a concrete blanket when the load is near the maximum load and after passing the maximum load the specimen is still able to give a large enough stretch until finally a local buckling occurs in the longitudinal reinforcement. This collapse behavior is almost the same as a column with uniaxial loading. This type of collapse model is shown in Fig. 3b.

Columns with external GFRP confinement (CR-1 L): The observation of the crack pattern occurring on the CR-1 L type of test specimen did not show significant cracking due to confinement with transversal and longitudinal reinforcement as well as with Glass Fiber Reinforced Polymer (GFRP) layers externally working properly. This type of collapse model is shown in Fig. 3c.

Columns with external GFRP confinement (CR-2L): Observation of the crack pattern occurring on the CR-2 L type of test specimen did not show significant cracking due to confinement with transverse and longitudinal reinforcement as well as with Glass Fiber Reinforced Polymer (GFRP) layers externally working properly. This type of collapse model is shown in Fig. 3d.

The strain stress curve for all specimens can be seen in Fig. 4 as a comparison of the column specimens studied. Concrete columns observed are specimens that use internal reinforcement steel confinement without the use of externally GFRP materials and concrete columns using externally GFRP materials. Figure 4 it can be seen that the presence of transverse and longitudinal reinforcement (RC specimen) can increase the axial tension stress. The most significant effect on the value of confinement is the CR-1L and CR-2L test specimens because in addition to using transverse and longitudinal reinforcement, it also uses GFRP materials as external confinement. Increased external GFRP confinement compared to the reinforced internal reinforcement specimen (RC) is 12.17%. These results indicate that with the use of GFRP materials as external confinement can increase the capacity of concrete columns. This is in line with what Mac Gregor suggests about the strength of concrete with triaxial loading of concrete (confinement) greater than with compressive uniaxial loading.

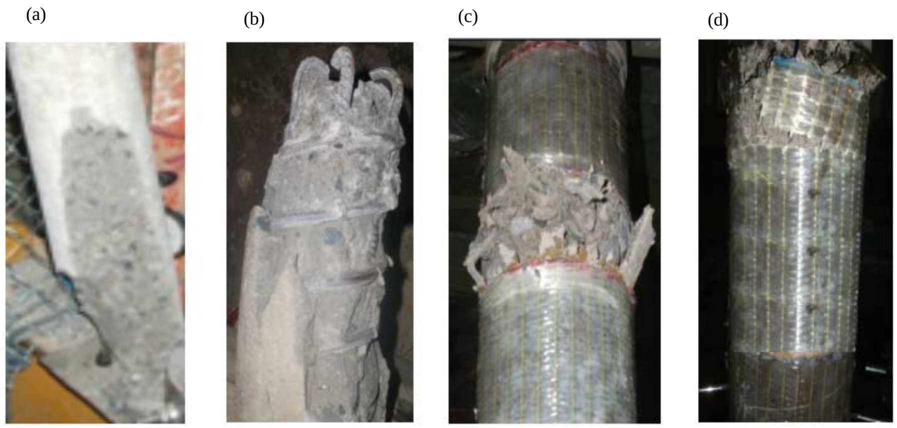

Fig. 3: Specimen failure models 1, 2, 3, 4: a) Specimen PC; b) Specimen RC; c) Specimen RC-1L and d) Specimen RC-2L

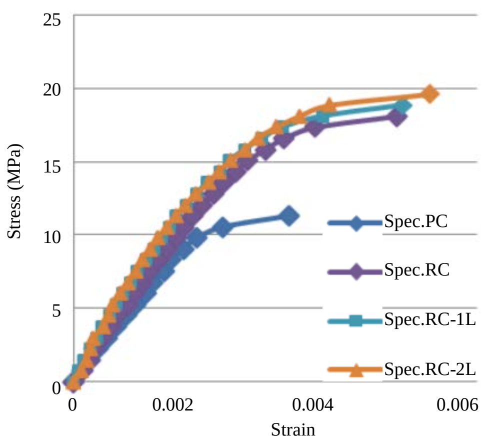

Fig. 4: Curve of strain stress specimen

Validation of experimental results

Validation of confined concrete strength values ($k_{eksperiment}$): The results of validation of confined concrete strength enhancement (K) with review of model formulation by previous researchers using triaxial test results can be seen in Table 2. The model reviewed by Campione and Miragle (2003), Li *et al*. (2005) and Lam and Teng (2003) Model.

The formulation equation of this model is further processed to find out the predicted increase in the strength of concreted concrete (K) as validation of the experimental results from the short column test of concrete unconfined with CFRP with concentric load. Validation was performed to determine the accuracy of each equation in predicting the increase in strength of concrete (K) concrete based on the experimental results. The three models reviewed each have a COV (Coefficient of Variation) value above 9%. Among the three models,

Table 2: Predicted COV value vs experimental result

Model	COV (%) for: ($K = f'_{cc}/f'_{cd}$)
Campione and Miraglia (2003)	9.12
Li *et al*. (2005)	9.87
Lam and Teng (2003)	10.23
Experimental result	10.73

Analysis results

the Lam and Teng Models have a higher COV value which is 10.71% which means closer to the experimental result with 11.13% COV value. While the model of Li *et al*. (2005) have a COV value of 10.07% and Campione and Miragle Models have a COV value of 9.27% against the experimental results. The third model reviewed is the predicted increase in strength of confined concrete (K) against the experimental results which is quite good because it has a COV value close to the experimental results.

Curved model validation of confined concrete strain stress for experimental result: Modeling of the relationship curve of confined concrete stress strain in the transverse and longitudinal reinforcement and the GFRP layer is externally formulated based on experimental results on 21 specimens in the form of Normal quality Concrete columns (NSC) and tested by concentric loading. The proposed strain stress curve is given one part based on the test result in the laboratory through a testing system using load control technique with stroke speed of 0.012 mm/sec. The test result of this model produce one part shape of strain stress curve that is ascending branch. The resulting model is then summarized and carefully observed model of experimental shape curves. Generally generated curves form a parabolic curve with peak coordinates (F'_{cc}, ε_{cc}). The results of the experimental model of experimental stress strain curve model with the comparison of several models from the previous researchers in Table 3. Meanwhile, for the model

Table 3: Model of confined concrete strain stress

Researchers	Model of confined concrete strain stress curve	
	Ascending branch	Descending branch
Lam and Teng (2003)	$f_c = E_c\ \varepsilon_c - \frac{(E_c - E_2)^2}{4\ foc}\ \varepsilon_c^2$	$f_c = f_{oc} + E_2\ \varepsilon_c$
Li *et al.* (2005)	$f_c^{'} = f_{c\,max}^{'} \left[2\frac{\varepsilon_c}{\varepsilon_{cmax}} - \left(\frac{\varepsilon_c}{\varepsilon_{c\,max}} \right)^2 \right]$	$f_c = f_{cmax} - E_{des}\ (\varepsilon_c - \varepsilon_{cmax})$
Campione and Miragle (2003)	$\frac{f_c}{f_{co}^{'}} = \frac{E_2}{E_1} \cdot \frac{\varepsilon_c}{\varepsilon_{co}} + \frac{\left(1 - \frac{E_2}{E_1}\right) \cdot \frac{\varepsilon_c}{\varepsilon_{co}}}{\left[1 + \left(\frac{\varepsilon_c}{\varepsilon_{co}^{'}} \right)^{n'} \right]^{\frac{1}{n'}}}$	-
Ayuddin Model (Experimental result)	$f_c = 10142\ (\varepsilon_c - 132.6\ \varepsilon_c^2)$	-

Experimental result, Lam and Teng Model, Li *et al.*, Model and Campione and Miragle Model

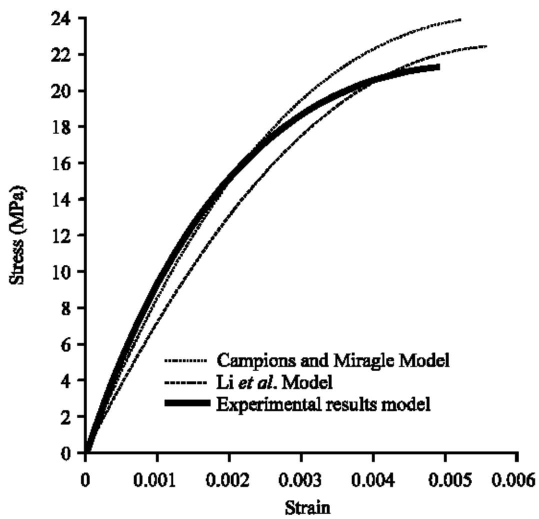

Fig. 5: Experimental result (Ayuddin Model) for unconfined concrete strain stress with Li *et al.* Model and Campione and Miragle Model and Campione and Miragle Model

of confined concrete strain sress curve for experimental result with two models reviewed namely (Li *et al.*, 2005; Campione and Miragle, 2003) Model shown in Fig. 5.

CONCLUSION

Based on the results of experimental studies that have been done, it can be concluded as follows. The calculation of the effectiveness of experimental confinement on the internal reinforced concrete column (RC) as well as the external reinforced concrete column of GFRP material (RC-1L) with a COV value of 10.73%. These results are considered good enough to see the results of validation of K values generated based on Lam and Teng Model, Li *et al.* Model and Campione and Miragle Models on experimental results, each having a COV value of 9.12, 9.87 and 10.23% COV values.

The addition of GFRP external Reinfor Cement (RC-1L) increased by 12.17% in strength compared to internal Reinforced Concrete columns (RC) and there was an increase in internal reinforced Concrete Columns (RC) into confined concrete columns with transverse reinforcement and longitudinal and confined external reinforcement of 2 layers GFRP material (RC-2L) of 21.74%.

The proposed strain stress constitution model can predict the GFRP stress strain curve model with model accuracy that is not much different from the Li *et al.* Model and the Campione and Miragle Model.

REFERENCES

Bisby, L.A., A.J. Dent and M.F. Green, 2005. Comparison of confinement models for fiber-reinforced polymer-wrapped concrete. ACI. Struct. J., 102: 62-72.

Campione, G. and N. Miraglia, 2003. Strength and strain capacities of concrete compression members reinforced with FRP. Cem. Concr. Compos., 25: 31-41.

Lam, L. and J.G. Teng, 2003. Design-oriented stress-strain model for FRP-confined concrete. Constr. Build. Mater., 17: 471-489.

Li, Y.F., S.H. Chen, K.C. Chang and K.Y. Liu, 2005. A constitutive model of concrete confined by steel reinforcements and steel jackets. Can. J. Civil Eng., 32: 279-288.

Toutanji, H., M. Han, J. Gilbert and S. Matthys, 2010. Behavior of large-scale rectangular columns confined with FRP composites. J. Comp. Constr., 14: 62-71.