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Improved Design-Oriented Confinement Models for FRP-Wrapped Concrete Cylinders based on Statistical Analyses

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ABSTRACT

This paper introduces improved design-oriented confinement models for cylindrical concrete members wrapped with fiber reinforced polymer (FRP) composites based on a rigorous statistical evaluation of a large database. As most of the existing design-oriented models for ultimate condition of FRP-confined concrete were developed based on limited experimental data points, a large experimental database of 518 cylindrical concrete specimens wrapped with unidirectional fabrics in the hoop direction with reported actual rupture strain of the wrap was compiled from the literature. The database is used to evaluate the performance of major existing strength and strain models. Then, using a general regression analysis, different forms of models are examined to obtain the best fit, and the performance of the models is compared to the existing models using the database. Based on two different statistical indices, the coefficient of determination (R^2) and the Root Mean Square Error (*RMSE*), the best performing strength and strain models are proposed for use in design applications. A parametric study is also performed on fiber type, cylinder diameter, concrete strength, and FRP wrap thickness, elastic modulus, and strength using the proposed models.

Keywords: Fiber reinforced polymer; FRP; Concrete; Column; Wrap; Confinement; Model; Stress; Strain; Design guideline.

1. INTRODUCTION

In the past two decades, many researchers studied the behavior of concrete members wrapped with externally bonded fiber reinforced polymer (FRP) composites and proposed a variety of confinement models for the ultimate condition of confined concrete under uniaxial compression loadings. The ultimate condition of an FRP-confined concrete refers to the axial compressive strength f'_{cc} and the ultimate axial strain ε_{cc}, as shown in Fig. 1(a). Many empirical models were proposed for the ultimate condition as simple expressions suitable for design guidelines and practical applications. One of the first studies to model FRP-confined concrete was implemented by Fardis and Khalili [1]. They examined two strength models for the compressive strength f'_{cc} adopted from Richart et al. [2] and Newman and Newman [3] and developed their own strain model for the ultimate axial strain ε_{cc}. Later, Mander et al. [4] developed new strength and strain models for concrete confined by transverse internal reinforcement, which were initially adopted by the ACI 440.2R-02 [5] design guideline for FRP-confined concrete. Because of the increasing popularity of FRPs, a new generation of confinement models was specifically developed by several researchers such as Karbhari and Gao [6], Samaan et al. [7], Toutanji [8], Lam and Teng [9], and Teng et al. [10]. Currently, the ACI 440.2R-08 [11] design guideline has adopted the models developed by Lam and Teng [9] with some minor modifications.

It should be mentioned that in most of the existing models proposed in the 90’s for FRP-confined concrete, actual rupture strains of hoop fibers were not considered and the models were developed based on ultimate tensile strain reported by the manufacturers or measured using flat coupons. In recent years, it has been well established that FRP wraps are ruptured at lower strains [9][12][13]. Most of the existing models were developed based on limited experimental data points with limited geometrical and mechanical variables such as specimen size, concrete strength, fiber type, and wrap thickness. The evaluation of these kinds of models with a large database of specimens is necessary and can lead to some improvements.

Traditionally, existing empirical models were developed based on a set of experimental data points and curve fitting techniques using spreadsheets, which typically have limited curve fitting functions and variables, where researchers are not able to cover all combinations of variables and functions to reach the best models. There is a gap in the field in terms of using a general regression analysis on a large set of experimental data points. In this paper, the authors evaluate the performance of major existing strength and strain models for FRP-confined concrete using a large experimental database on cylindrical concrete specimens wrapped with unidirectional fabrics in the hoop direction. After statistical evaluations, and based on the performance of existing models and using a general analytical procedure for curve fitting, a set of improved empirical design-oriented models are proposed and verified with the experimental database. At the end, proposed models are examined through a parametric study on different material and geometric parameters.

2. EXPERIMENTAL DATABASE

Many experimental research programs were conducted on FRP-confined concrete specimens under uniaxial compressive loading. In the present study, a database containing the test results of 518 cylindrical concrete specimens wrapped with unidirectional fabrics in the hoop direction was compiled from the literature, as shown in Table 1. A total of 454 data points were adopted from Sadeghian and Fam [16] and the rest of the specimens (a total of 64 data points) were recently added in the current study. It should be mentioned that the current database contains 518 cylindrical specimens with the required key parameter which is the measured reduced hoop rupture strain of FRP wraps to evaluate the actual confining pressure at failure point.

The current database contains cylindrical specimens having diameter D ranging from 51 to 406 mm with an average (AVG) of 158 mm and a standard deviation (SD) of 53 mm; and unconfined concrete strength f'_{co} of 19.7 to 188.2 MPa with an AVG of 46.5 MPa and a SD of 27.0 MPa. All specimens were wrapped with unidirectional FRPs in the hoop direction. As shown in the column "Fiber type" in Table 1, 388 specimens were wrapped with carbon-FRP as indicated by "C", 114 specimens were wrapped with glass-FRP as indicated by "G", and 16 specimens were wrapped with aramid-FRP as indicated by "A". Most of the specimens were made of plain concrete (i.e., no internal reinforcements), however 26 specimens contained internal axial and transverse steel reinforcements as indicated by "R", 6 specimens contained an internal hollow steel tube with a 76.1 mm outer diameter and a 3.2 mm thickness as indicated by "T", 5 specimens contained a 50 mm internal hole as indicated by "H", and 6 specimens were made of ultra-high performance concrete as indicated by "U" in Table 1.

In the database, the sources of information on mechanical properties of FRPs are different. As shown in the last column of Table 1, the source of the information for 313 specimens is flat coupon tests as indicated by "F", for 116 specimens is the manufacturer data sheet as indicated by "M", for 6 specimens is the split disk test as indicated by "S", and for 83 specimens the source of the information is not available as indicated by "N". Based on the literature, researchers reported the elastic modulus E_f and ultimate tensile strength f_{fu} of FRP wraps in the hoop direction, where E_f varies from 11 to 663 GPa with an AVG of 183 GPa and a SD of 125 GPa; and f_{fu} varies from 220 to 4441 MPa with an AVG of 2603 MPa and a SD of 1438 MPa. It should be noted that some researchers reported a nominal thickness of FRP wraps and the rest have reported the actual thickness. Most importantly is that the reported mechanical properties of FRP wraps are consistent with the reported thickness. FRP thickness t varies from 0.09 to 7.26 mm with an AVG of 0.89 mm and a SD of 1.06 mm.

As shown in Table 1, the principal experimental results are the ultimate axial strength of the confined concrete f'_{cc} ranging from 31.4 to 372.2 MPa with an AVG of 83.2 MPa and a SD of 43.27 MPa, the ultimate axial strain of confined concrete ε_{cc} ranging from 0.23% to 6.20% with an AVG of 1.68% and a SD of 1.05%, and the FRP hoop rupture strain $\varepsilon_{h,rup}$ ranging from 0.10% to 4.98% with an AVG of 1.12% and a SD of 0.53%. Some of the test data reported by the researchers represent the average of two or three nominally identical physical specimens.

3. EVALUATION OF EXISTING MODELS

3.1. Statistical Methods

This section evaluates the performance of existing confinement models for FRP-confined concrete using the experimental database presented in the previous section. In all evaluations, the values predicted by strength and strain models are compared with experimental values. Two indices, namely the coefficient of determination (R^2) and the Root Mean Square Error (*RMSE*), are used for the evaluations. R^2 is the square of the correlation coefficient which is defined to determine the relationship between predicted and experimental values as:

$$R^2(X,Y)=\left(\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}\right)^2 \tag{1}$$

where X and Y are the vector of experimental and predicted values, respectively; x and y are experimental and predicted values, respectively; and $\bar{x}$ and $\bar{y}$ are the averages of experimental and predicted values, respectively. R^2 ranges from zero to one, with one indicating a perfect correlation between predicted and experimental values and zero indicating no correlation. The important point is that $R^2 = 1$ does not guarantee a perfect prediction. It only shows that there is a linear correlation between predicted and experimental values. Thus, R^2 is not the most proper index for this kind of evaluation. Instead, another statistical index, *RMSE,* is implemented to evaluate the accuracy of predictions. *RMSE* is the square root of the variance of the residuals which is defined as the following:

$$RMSE = \sqrt{\frac{\sum (x-y)^2}{n}} \qquad (2)$$

where n is the number of data points. *RMSE* indicates how close the predicted values (i.e., y) to the experimental values (i.e., x). While R^2 is a relative measure of fit, *RMSE* is an absolute measure of fit without any upper limit. Lower values of *RMSE* indicate a better fit, with zero indicating a perfect prediction that means all data points are located on a 45-degree line ($R^2 = 1$). For a hypothetical case, if all data points were located on a 10-degree line which is clearly a poor prediction, R^2 would be equal to one whereas *RMSE* would be able to show the poor prediction. Indeed, R^2 is not intended to evaluate “experimental vs. analytical” data along the 45-degrees line. For this reason, preciously the authors choose *RMSE* index in this work, which is more appropriate than R^2 in the context of the current study.

It should be noted that preliminary evaluations showed that a few experimental data points of the database were very poorly predicted by 6 existing and well known but different models. Thus, those data points (as marked in Table 1) are eliminated from further evaluations to prevent saturation of the *RMSE* index with the square of large errors values i.e. $(x\text{-}y)^2$ in Eq. 2. The eliminated data points include 9 points related to f'_{cc} and 13 points related to ε_{cc} that showed more than a 50% error in f'_{cc} prediction and a 100% error in ε_{cc} prediction. Thus, strength and strain models are evaluated using 509 and 505 data points, respectively. It should be mentioned that the current evaluations cover design-oriented confinement models with empirical equations for f'_{cc} and ε_{cc} only and not analysis-oriented models (for examples, see [17][18][19]).

3.2. Mechanics of Confinement

Existing strength and strain models utilize some common parameters, including the maximum confinement stress f_l, the confinement stiffness ratio ρ_K, and the strain ratio ρ_ε. The last two parameters were introduced by Teng et al. [10], where ρ_K represents the stiffness of the FRP wrap relative to that of the concrete core and ρ_ε is a measure of the strain capacity of the FRP wrap. Based on Fig. 1(b) and the mechanics of confinement in FRP-confined concrete, the mathematical expression of the maximum confinement stress f_l is defined as follows:

$$f_l = \rho_K \rho_\varepsilon f'_{co} = \frac{2E_f \varepsilon_{h,rup} t}{D} \tag{3}$$

$$\rho_K = \frac{2E_f t}{\left(f'_{co} / \varepsilon_{co}\right) D} \tag{4}$$

$$\rho_\varepsilon = \frac{\varepsilon_{h,rup}}{\varepsilon_{co}} \tag{5}$$

where f'_{co} is the unconfined concrete strength, ε_{co} is the corresponding axial strain of f'_{co}, E_f is the elastic modulus of the FRP wrap in the hoop direction, t is the total thickness of the FRP wrap, $\varepsilon_{h,rup}$ is the actual hoop rupture strain of the FRP wrap, and D is the diameter of the concrete core. The confinement ratio f_l / f'_{co} is a frequently used parameter in existing confinement models, which is equal to the product of ρ_K and ρ_ε. Based on Teng et al. [10], instead of the more approximate value of 0.002 for ε_{co}, it is assumed as the following (f'_{co} in MPa):

$$\varepsilon_{co} = 9.37 \times 10^{-4} \sqrt[4]{f'_{co}} \tag{6}$$

It should be mentioned that f_l is the maximum possible confining pressure provided by the FRP wrap when it fails due to hoop tensile stresses. The failure usually happens at a lower level of stress compared to ultimate uniaxial hoop strength of flat FRP coupons. This phenomenon is defined by a strain efficiency factor which was studied by the authors in a separate paper [16]. In fact, some old models such as Richart et al. [2], Newman and Newman [3], and Mander et al. [4] were developed based on concrete confined with steel stirrups. Some models for FRP-confined concrete such as Fardis and Khalili [1], Karbhari and Gao [6], and Samaan et al. [7] did not consider the strain efficiency of the FRP wraps and predicted f_l using the ultimate uniaxial hoop strength of the FRP. In the current study, these models are evaluated using the actual hoop rupture strain $\varepsilon_{h,rup}$.

3.3. Existing Strength and Strain Models

In this section, major existing strength models (i.e. models for f'_{cc}) and strain models (i.e. models for ε_{cc}) are selected and evaluated using the database. The selected models are Richart et al. [2], Newman and Newman [3], Fardis and Khalili [1], Mander et al. [4], Karbhari and Gao [6], and Samaan et al. [7], Toutanji [8], Lam and Teng [9], and Teng et al. [10]. The models were selected based on their wide use in the literature due to their ease of application. Most of these models have both strength and strain expressions; however, a few have only either a strength or strain component.

3.3.1. Richart et al. [2] Model: The model, given by Eq. (7), is one of the oldest strength models developed for concrete under active confinement and verified for confined concrete with steel stirrups. This model was adopted by Fardis and Khalili [1] for FRP-confined concrete. The model predicts the ratio of f'_{cc} / f'_{co} as a linear function of the confinement ratio f_l / f'_{co}. The model does not have a strain component. Using the database with 509 data points, the performance of this model is shown in Fig. 2(a) with R^2=0.893 and *RMSE*=0.441. Despite that the model was not developed for FRP-confined concrete, its performance is relatively good. This confirms that developing a linear function can still be an appropriate approach.

$$\frac{f'_{cc}}{f'_{co}} = 1 + 4.1\frac{f_l}{f'_{co}} \tag{7}$$

3.3.2. Fardis and Khalili [1] Model: The model, expressed in Eq. (8), is the first model which was developed for FRP-confined concrete. The ultimate axial strain ε_{cc} increases with the relative circumferential stiffness of the FRP wrap and concrete. Using the database with 505 data points, the performance of this model is shown in Fig. 3(a) with R^2=0.223 and *RMSE*=6.932. The indices and the figure show that data points are scattered, thus the relative circumferential stiffness may not be a suitable parameter for this prediction. It should be noted that strain models demonstrate larger *RMSE* compared to strength models because the nature of strain measurements has more uncertainty.

$$\varepsilon_{cc} = 0.002 + 0.001\frac{E_f t}{D f'_{co}} \tag{8}$$

3.3.3. Newman and Newman [3] Model: The model, given by Eq (9), was developed for confined concrete with steel stirrups. The model predicts the strength ratio of f'_{cc} / f'_{co} as a power function of the confinement ratio f_l / f'_{co}. Using the database, the performance of this model is shown in Fig. 2(b) with R^2=0.898 and *RMSE*=0.398. The prediction is a little overestimated and *RMSE* suggests that this power function is not able to predict the strength ratio as good as the linear model by Richart et al. [2]. However, by modifying the constant factors of the model, the power form might work better.

$$\frac{f'_{cc}}{f'_{co}} = 1 + 3.7\left(\frac{f_l}{f'_{co}}\right)^{0.86} \tag{9}$$

3.3.4. Mander et al. [4] Model: The nonlinear strength and strain models, expressed in Eq. (10) and Eq. (11), were developed for confined concrete with steel stirrups. The models were adopted by Saadatmanesh et al. [20] and the ACI 440.2R-02 [5] for FRP-confined concrete. Using the database, the performance of the strength model is shown in Fig. 2(c) with R^2=0.819 and *RMSE*=0.464. The strength model is a little conservative for FRP-confined concrete, but the *RMSE* index demonstrates that its general performance is very similar to the two previous strength models.

$$\frac{f'_{cc}}{f'_{co}} = 2.254\sqrt{1 + 7.94\frac{f_l}{f'_{co}}} - 2\frac{f_l}{f'_{co}} - 1.254 \tag{10}$$

$$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + 5\left(\frac{f'_{cc}}{f'_{co}} - 1\right) \tag{11}$$

The performance of the strain model is shown in Fig. 3(b) with R^2=0.715 and *RMSE*=3.089, where the experimental values of f'_{cc} are implemented. The indices and figure show that the performance of the strain model is significantly better than the previous strain model shown in Fig. 3(a). The model demonstrates that in the case of no confinement (i.e., $f'_{cc}=f'_{co}$), ε_{cc} equals to ε_{co}. Moreover, based on the strength models developed by Richart et al. [2] and Newman and Newman [3], the second term of the current model (i.e., f'_{cc} / f'_{co} -1) is a function of the confinement ratio f_l / f'_{co}.

3.3.5. Karbhari and Gao [6] Model: The strength and strain models are among the early models of FRP-confined concrete and are given in Eq. (12) and Eq. (13). It was assumed that FRP wrap is able to reach its full tensile strength in the hoop direction, which we now know is not possible. The strength model implemented a power function, same as Newman and Newman

[3], but with different constants. Using the database, the performance of the strength model is shown in Fig. 2(d) with R^2=0.898 and *RMSE*=0.501. The model provides a good prediction for low strength ratios, however its performance for high values is not as good. The *RMSE* index demonstrates this problem, whereas R^2 is not able to indicate it.

$$\frac{f'_{cc}}{f'_{co}} = 1 + 2.1\left(\frac{f_l}{f'_{co}}\right)^{0.87} \tag{12}$$

$$\varepsilon_{cc} = \varepsilon_{co} + 0.01\frac{f_l}{f'_{co}} \tag{13}$$

For the strain model, Karbhari and Gao [6] realized that ε_{cc} is unaffected by the modulus of the FRP wrap, but is controlled by the confining pressure developed by the wrap, as shown in Eq. (13). This is consistent with the models developed for confined concrete with steel stirrups such as Mander et al. [4], which was followed by other researchers for FRP-confined concrete. The strain model is expressed using a linear relationship with the confinement ratio. Using the database, the performance of this model is shown in Fig. 3(c) with R^2=0.613 and *RMSE*=6.517. The indices and figure demonstrate that the model is too conservative.

3.3.6. Samaan et al. [7] Model: The strength and strain models, expressed in Eq. (14) and Eq. (15), were originally developed for concrete-filled FRP tubes (CFFTs). Later, it was confirmed by Shahawy et al. [21] that the models can also be applied for concrete members wrapped with FRPs. Moreover, it was noted that the effective hoop rupture strain of the wrap is often less than that obtained from the uniaxial tensile coupon tests, and the premature failure must be avoided by setting proper confidence levels in a reliability analysis for the effective rupture strain. Using the database, the performance of the strength model is shown in Fig. 2(e) with R^2=0.901 and *RMSE*=0.437.

$$f'_{cc} = f'_{co} + 6.0 f_l^{0.7} \qquad (14)$$

$$\varepsilon_{cc} = \frac{f'_{cc} - f_o}{E_2} \qquad (15)$$

where

$$f_o = 0.872 f'_{co} + 0.371 f_l + 6.258 \qquad (16)$$

$$E_2 = 245.61 f'^{0.2}_{co} + 1.3456 \frac{E_f t}{D} \qquad (17)$$

The strain model is a function of f'_{cc}, E_2 as the second slope of the bilinear stress-strain curve of confined concrete (in MPa), and f_o as the intercept of the second slope with stress axis (in MPa). Using the database, the performance of the strain model is shown in Fig. 3(d) with R^2=0.598 and *RMSE*=4.604, where the experimental values of f'_{cc} are implemented. The indices and figure demonstrate that the model overestimates ε_{cc} of most of the data points, and the predicted points are scattered. The reason may be that the model is highly dependent on the parameters of E_2 and f_o which were originally calibrated with CFFT test results.

3.3.7. Toutanji [8] Model: The strength and strain models are expressed as Eq. (18) and (19), respectively. The strength model has a power form with constant parameters of values between those in the models by Newman and Newman [3] and Karbhari and Gao [6]. Using the database, the performance of the strength model is shown in Fig. 2(f) with R^2=0.898 and *RMSE*=0.354. The index of *RMSE* and the visual evaluations of the recent three models developed based on FRP-confined concrete in Figs. 2(d), (e), and (f) are not significantly better than the first three models developed based on steel stirrups, shown in Figs. 2(a), (b), and (c).

$$\frac{f'_{cc}}{f'_{co}} = 1 + 3.5\left(\frac{f_l}{f'_{co}}\right)^{0.85} \qquad (18)$$

$$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + \left(310.57\varepsilon_{h,rup} + 1.90\right)\left(\frac{f'_{cc}}{f'_{co}} - 1\right) \tag{19}$$

The strain model, given in Eq. (19), was the first model for ε_{cc} which directly included a new term related to the actual rupture strain $\varepsilon_{h,rup}$ of the wrap. Using the database, the performance of the model is shown in Fig. 3(e) with R^2=0.787 and *RMSE*=3.361. The performance of the model is relatively good. This clarifies that having a separate term for $\varepsilon_{h,rup}$ is reasonable.

3.3.8. Lam and Teng [9] Model: The strength and strain models are expressed in Eq. (20) and Eq. (21), respectively. The models were developed for confined concrete with FRP wraps based on 76 data points and considering the actual failure strain of FRP in the hoop direction. The models were adopted by the ACI 440.2R-08 [11] design guideline for FRP-confined concrete with some modifications. Using the database, the performance of the strength model is shown in Fig. 2(g) with R^2=0.898 and *RMSE*=0.291. While the model adopted a simple linear form, the *RMSE* index and visual evaluation demonstrate that its performance is the best compared to the previous models.

$$\frac{f'_{cc}}{f'_{co}} = 1 + 3.3\frac{f_l}{f'_{co}} \tag{20}$$

$$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.75 + 12\rho_K \rho_\varepsilon^{1.45} \tag{21}$$

The strain model, given in Eq. (21), was the first to have separate parameters for the confinement stiffness ρ_K and the FRP strain capacity ρ_ε. Using the database, the performance of the strain model is shown in Fig. 3(f) with R^2=0.668 and *RMSE*=5.495. While, the figure demonstrates that the prediction is a little overestimated and *RMSE* is not as good as the model developed by Toutanji [8], the form of the model is novel.

3.3.9. Teng et al. [10] Model: The models developed by Lam and Teng [9] for FRP-confined concrete were refined based on 18 data points. The database was limited, but all points were measured under well-defined conditions. Two forms of nonlinear and linear strength models were developed. These models allow the effects of the confinement stiffness ρ_K and the FRP strain capacity ρ_ε to be separately reflected and also account for the effect of confinement stiffness explicitly instead of having it reflected only through the confinement ratio f_l / f'_{co}. The nonlinear and linear strength models are expressed as follows:

$$\frac{f'_{cc}}{f'_{co}} = 1 + \left(3.2\rho_K^{0.9} - 0.06\right)\rho_\varepsilon \tag{22}$$

$$\frac{f'_{cc}}{f'_{co}} = 1 + 3.5\left(\rho_K - 0.01\right)\rho_\varepsilon \tag{23}$$

Using the database, the performance of the nonlinear strength model is shown in Fig. 2(h) with R^2=0.898 and *RMSE*=0.308. The performance of linear strength model is also shown in Fig. 2(i) with R^2=0.892 and *RMSE*=0.319. The *RMSE* indices and visual evaluations demonstrate that the performance of the models is not as good as Lam and Teng [9], but the approach proposed to separate the confinement ratio into two parameters of ρ_K and ρ_ε is valuable. For the strain model, given in Eq. (24), the form of the model was kept similar to Lam and Teng [9] and the constants were updated. Using the database, the performance of the strain model is shown in Fig. 3(g) with R^2=0.696 and *RMSE*=3.791. So far, this model is the best model for ε_{cc} which has the minimum *RSME* compared to other models.

$$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.75 + 6.5\rho_K^{0.8}\rho_\varepsilon^{1.45} \tag{24}$$

4. IMPROVED CONFINEMENT MODELS

This section proposes improved empirical models to predict the ultimate condition of FRP-confined concrete (i.e. f'_{cc} and ε_{cc}). The improved models are developed using a general regression analysis based on minimizing an errors function. The errors function is defined as the sum of squared errors between predicted and experimental values. Some spreadsheet programs such as Microsoft Office Excel utilize this technique, but they employ predefined regression models that have some limitations including the number of parameters. The advantages of the general regression analysis which is used in the current study are that the form of model can be selected and the number of parameters is unlimited. Another new aspect of the study is using the large experimental database with all required parameters in the general regression analysis.

4.1. General Regression Analysis Procedure

In this section, the procedure of the general regression analysis is explained. The first step is selecting a form for the model. Here, as an example, a form as the equation below is selected for f'_{cc}. There is no limitation on the forms and number of parameters and constants.

$$\frac{f'_{cc}}{f'_{co}} = 1 + k\left(\frac{f_l}{f'_{co}}\right)^{\lambda} \tag{25}$$

where k and λ are constants which need to be calculated for this specific model. The error e_i for the data point number i is defined as the difference between the predicted value (with the superscription of P) and the experimental value (with no superscription) as follows:

$$e_i = \left(\frac{f'_{cc}}{f'_{co}}\right)_i^P - \left(\frac{f'_{cc}}{f'_{co}}\right)_i \tag{26}$$

With substituting the predicted value from Eq. (25) in Eq. (26), the error e_i is expanded as follows:

$$e_i = 1 + k\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda} - \left(\frac{f'_{cc}}{f'_{co}}\right)_i \tag{27}$$

The errors function *f* is defined as the sum of squared errors as the following:

$$f(k,\lambda) = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n}\left[1 + k\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda} - \left(\frac{f'_{cc}}{f'_{co}}\right)_i\right]^2 \tag{28}$$

where *n* is the number of data points in the database which is 509 for strength models and 505 for strain models in this study. In order to obtain the best fit, the errors function should be minimized through the derivation with respect to the constants *k* and *λ*, as expressed below:

$$\frac{\partial f}{\partial k} = 0 \rightarrow \sum_{i=1}^{n}\left\{\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda}\left[1 + k\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda} - \left(\frac{f'_{cc}}{f'_{co}}\right)_i\right]\right\} = 0 \tag{29}$$

$$\frac{\partial f}{\partial \lambda} = 0 \rightarrow \sum_{i=1}^{n}\left\{\left[Ln\left(\frac{f_l}{f'_{co}}\right)_i\right]\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda}\left[1 + k\left(\frac{f_l}{f'_{co}}\right)_i^{\lambda} - \left(\frac{f'_{cc}}{f'_{co}}\right)_i\right]\right\} = 0 \tag{30}$$

The constants *k* and *λ* can be calculated using Eq. (29) and (30) as there are two unknowns and two equations. As seen, the equation can be long and complicated as the summations are expanded based on the number of data points (e.g., more than 500 data points), especially when adopting advanced nonlinear forms and having many constants. Thus, an iterative solution using a general data processing software such as Mathcad is required. The regression analysis procedure as explained is implemented to develop improved empirical models with different forms for f'_{cc} and ε_{cc}. It should be noted that the forms are selected based on the performance of the existing models explained in the previous section. Final decisions on the best forms are made after evaluation of all selected forms and comparison with the existing models.

4.2. Improved Strength Models

Based on the forms of existing models and the evaluation of their performance using the experimental database, five types of models for f'_{cc} are selected (i.e., Types 1 to 5) as shown in the first term on the right side of Eq. (31) to Eq. (35), respectively. Using the procedure explained in the previous section, the errors function *f*, given as an example in Eq. (28), is defined and minimized with respect to the constant factors for each model. For model Type 1, there are two constant factors *k* and λ, so there are two equations (i.e., Eq. (29) and (30)) to find the factors. For the models with more constant factors, there are similarly more equations. For example, model Type 5 has five constants *k*, λ_1, λ_2, μ_1, and μ_2, so there are five equations based on five separate derivations with respect to each factor to find the factors. For each model, the system of nonlinear equations is solved using an iterative solution technique on 509 data points. The results of the general regression analysis for models Type 1 to 5 are expressed as the second term on the right side of the following equations, respectively:

Type 1: $$\frac{f'_{cc}}{f'_{co}}=1+k\left(\frac{f_l}{f'_{co}}\right)^{\lambda}=1+3.18\left(\frac{f_l}{f'_{co}}\right)^{0.94}=1+3.18\rho_K^{0.94}\rho_\varepsilon^{0.94} \tag{31}$$

Type 2: $$\frac{f'_{cc}}{f'_{co}}=1+k\rho_K^{\lambda_1}\rho_\varepsilon^{\lambda_2}=1+3.48\rho_K^{0.96}\rho_\varepsilon^{0.91} \tag{32}$$

Type 3: $$\frac{f'_{cc}}{f'_{co}}=1+\left(k\rho_K^{\lambda}+\mu\right)\rho_\varepsilon=1+\left(2.39\rho_K^{0.78}-0.06\right)\rho_\varepsilon \tag{33}$$

Type 4: $$\frac{f'_{cc}}{f'_{co}}=1+\left(k\rho_K^{\lambda_1}+\mu\right)\rho_\varepsilon^{\lambda_2}=1+\left(2.77\rho_K^{0.77}-0.07\right)\rho_\varepsilon^{0.91} \tag{34}$$

Type 5: $$\frac{f'_{cc}}{f'_{co}}=1+\left(k\rho_K^{\lambda_1}+\mu_1\right)\left(\rho_\varepsilon^{\lambda_2}+\mu_2\right)=1+\left(1.58\rho_K^{0.78}-0.04\right)\left(\rho_\varepsilon^{1.15}+1.14\right) \tag{35}$$

The performance of the improved strength models Type 1 to 5 are shown in Figs. 4(a) to 4(e), respectively. The figures demonstrate that the performances of the improved models are significantly better than the existing models considered in Fig. 2. For better comparison, the indices of *RMSE* and R^2 for all existing and improved models are compared in Fig. 5. As expected, it is clear that R^2 is not able to differentiate between the models. Using *RMSE*, however, the figure shows that the improved models have significantly better performance compared to the models developed by Richart et al. [2], Newman and Newman [3], Mander et al. [4], Karbhari and Gao [6], Samaan et al. [7], and Toutanji [8], Lam and Teng [9] and Teng et al. [10]. Furthermore, the improved models Type 1 and 2 demonstrate an almost similar performance, while increasing the number of constants in improved models Type 3 to 5 decreases the index of *RMSE*, which is desirable. Considering the performance of the improved models and having a simple practical equation to be used by engineers, model Type 4, which also has the minimum *RMSE*, is selected as the proposed strength model as follows, where ρ_K and ρ_ε are defined in Eq. (4) and (5).

$$\frac{f'_{cc}}{f'_{co}} = 1 + \left(2.77\rho_K^{0.77} - 0.07\right)\rho_\varepsilon^{0.91} \tag{36}$$

4.3. Improved Strain Models

Using the procedure explained for the improved strength models, seven types of models for ε_{cc} are selected and their constants are calculated as follows:

Type 1: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + k\left(\frac{f_l}{f'_{co}}\right)^{\lambda} = 1 + 15.93\left(\frac{f_l}{f'_{co}}\right)^{0.69} = 1 + 15.93\rho_K^{0.69}\rho_\varepsilon^{0.69} \tag{37}$$

Type 2: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.5 + k\left(\frac{f_l}{f'_{co}}\right)^{\lambda} = 1.5 + 15.40\left(\frac{f_l}{f'_{co}}\right)^{0.73} = 1.5 + 15.40\rho_K^{0.73}\rho_\varepsilon^{0.73} \tag{38}$$

Type 3: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + k\rho_K^{\lambda_1}\rho_\varepsilon^{\lambda_2} = 1 + 6.47\rho_K^{0.65}\rho_\varepsilon^{1.15} \tag{39}$$

Type 4: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.5 + k\rho_K^{\lambda_1}\rho_\varepsilon^{\lambda_2} = 1.5 + 6.78\rho_K^{0.63}\rho_\varepsilon^{1.08} \quad (40)$$

Type 5: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + \left(k\rho_K^{\lambda_1} + \mu\right)\rho_\varepsilon^{\lambda_2} = 1 + \left(7.21\rho_K^{0.58} - 0.07\right)\rho_\varepsilon^{1.03} \quad (41)$$

Type 6: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.5 + \left(k\rho_K^{\lambda_1} + \mu\right)\rho_\varepsilon^{\lambda_2} = 1.5 + \left(6.61\rho_K^{0.61} - 0.06\right)\rho_\varepsilon^{1.09} \quad (42)$$

Type 7: $$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1 + \left(k\rho_K^{\lambda_1} + \mu_1\right)\left(\rho_\varepsilon^{\lambda_2} + \mu_2\right) = 1 + \left(6.48\rho_K^{0.59} - 0.03\right)\left(\rho_\varepsilon^{1.07} + 0.24\right) \quad (43)$$

The performance of the improved strain models Type 1 to 7 are shown in Figs. 6(a) to 6(g), respectively. The figures demonstrate that the performance of the improved models is significantly better than the existing models considered in Fig. 3. For better comparison, the indices *RMSE* and R^2 for all existing and improved models are compared in Fig. 7. For *RMSE*, the figure shows that the improved models have significantly better performance compared to the existing models. The improved models Type 3 and 7 have slightly better performance compared to Type 1 and 2. Considering the performance of the improved models and having a simple practical equation, improved model Type 4 is selected as the proposed strain model as given by Eq. (44), where ρ_K and ρ_ε are defined as Eqs. (4) and (5). For an extreme case with no FRP, the constant of 1.5 predicts an ultimate strain of 0.003 based on the common value of 0.002 for ε_{co}, which is consistent with plain concrete.

$$\frac{\varepsilon_{cc}}{\varepsilon_{co}} = 1.5 + 6.78\rho_K^{0.63}\rho_\varepsilon^{1.08} \quad (44)$$

4.4. Parametric Study

In this section, the proposed strength and strain models are used in a parametric study to investigate the effects of key parameters on the models' prediction, including: (a) geometric parameters (cylinder diameter D and FRP wrap thickness t); and (b) mechanical properties (unconfined concrete strength f'_{co}, FRP wrap strength f_{fu}, and FRP wrap modulus E_f). It should be mentioned that FRP wraps are unidirectional in the hoop direction of concrete cylinders. For each case in the parametric study, the objective is to study the variation of f'_{cc} and ε_{cc} against that specific parameter. In order to have a better understanding about the effect of each parameter on the x-axis, another parameter (D or t) is changed to have a series of curves for comparison. While each two parameters are being investigated, other parameters are kept constant. The default parametric values are f'_{co} = 40 MPa, t = 0.75 mm (3 plies, each ply = 0.25 mm), f_{fu} = 2500 MPa, and E_f = 200 GPa. In order to be consistent, it is assumed the strain efficiency factor is 0.55 as suggested by the ACI 440.2R-08.

4.4.1. Effect of Concrete Diameter: The range of concrete cylinder diameter D studied was 50 to 600 mm. Fig. 8(a) shows the variation of the confined strength ratio f'_{cc} / f'_{co} against the diameter D for different FRP layers (1 to 5 layers). As shown, increasing diameter D decreases the confined strength ratio; however, the ratio drops more for higher FRP layers as diameter D increases. For example, for 1 layer of FRP (t=0.25 mm), increasing D from 50 to 600 mm resulted in a 54.1% decrease in confined strength ratio (i.e., decreasing from 2.23 to 1.02); and for 5 layers of FRP (t=1.25 mm), it resulted in a 73.1% decrease (i.e., decreasing from 5.70 to 1.54). Fig. 9(a) shows the variation of confined strain ratio ε_{cc} / ε_{co} against diameter D. As shown, the variation has a similar pattern as the confined strength ratio. For example, for 1 layer of FRP, increasing D from 50 to 600 mm resulted in a 62.4% decrease in the confined strain ratio (i.e., decreasing from 7.10 to 2.67); and for 5 layers of FRP, it resulted in a 72.1% decrease (i.e., decreasing from 16.94 to 4.73). It should be mentioned that the models were verified against the database containing specimens with diameter from 51 to 406 mm only, thus predictions for diameters beyond this range should be verified with further research.

4.4.2. Effect of FRP Thickness: The range of FRP thickness t studied was 0.25 to 2.5 mm, which corresponds to 1 to 10 layers of FRP. Fig. 8(b) shows the variation of confined strength ratio f'_{cc} / f'_{co} against FRP thickness t for a different concrete diameter D (50 to 600 mm). As shown, increasing the number of FRP layers increases the confined strength ratio with almost a linear rate; however, the rate of the increase is larger for smaller concrete diameters. For example, at D=150 mm, increasing t from 0.25 to 2.5 mm resulted in a 208.7% increase in the confined strength ratio (i.e., from 1.42 to 4.39); and at D=600 mm, it resulted in a 99.7% increase only (i.e., from 1.02 to 2.04). Fig. 9(b) shows the variation of the confined strain ratio $\varepsilon_{cc} / \varepsilon_{co}$ against FRP thickness t. As shown, the variation has a similar pattern as the confined strength ratio. For example, at D=150 mm, increasing t from 0.25 to 2.5 mm resulted in a 212.8% increase in the confined strain ratio (i.e. from 4.30 to 13.46); and at D=600 mm, it resulted in a 143.2% increase (i.e., from 2.67 to 6.49). In general, the more FRP layer is better.

4.4.3. Effect of Unconfined Concrete Strength: The range of unconfined concrete strength f'_{co} studied was 20 to 130 MPa. Figs. 8(c) and 9(c) show the variation of f'_{cc} / f'_{co} and $\varepsilon_{cc} / \varepsilon_{co}$ against f'_{co} for a different concrete diameter D (50 to 600 mm), respectively. As shown, decreasing concrete strength increases the confined strength ratio; however, the increase drops for larger diameters. For example, at D=150 mm, decreasing f'_{co} from 60 to 20 MPa resulted in a 76% increase in the confined strength ratio; and at D=400 mm, it resulted in a 48% increase. In terms of strain, at D=150 mm, decreasing f'_{co} from 60 to 20 MPa resulted in a 93% increase in the confined strength ratio; and at D=400 mm, it resulted in a 75% increase. For example, at D=150 mm, decreasing f'_{co} from 130 to 20 MPa resulted in a 131.4% increase in the confined strength ratio (i.e., from 1.41 to 3.25); and at D=600 mm, it resulted in a 56.0% increase only (i.e. from 1.05 to 1.63). Fig. 9(c) shows the variation of confined strain ratio ε_{cc} / ε_{co} against f'_{co}. As shown, the variation has a similar pattern as the confined strength ratio. For example, at D=150 mm, decreasing f'_{co} from 130 to 20 MPa resulted in a 183.5% increase in the confined strength ratio (i.e., from 3.84 to 10.87); and at D=600 mm, it resulted in a 118.7% increase only (i.e., from 2.48 to 5.41). In general, FRP wrappings are more effective on low strength concrete members in terms of both strength and ductility.

4.4.4. Effect of FRP Elastic Modulus: The range of FRP elastic modulus E_f (in hoop direction) studied was 50 to 550 GPa. Figs. 12(d) and 13(d) show the variation of f'_{cc} / f'_{co} and ε_{cc} / ε_{co} against E_f for a different concrete diameter D (50 to 600 mm), respectively. As shown, changing the FRP elastic modulus has no significant effect on the confined strength ratio for a given diameter. However, decreasing the FRP elastic modulus increases the confined strain ratio, significantly. For example, at D=150 mm, decreasing E_f from 550 to 50 GPa resulted in a 136.5% increase in the confined strength ratio (i.e., from 5.05 to 11.95); and at D=600 mm, it resulted in a 95.6% increase (i.e., from 2.98 to 5.86). Clearly, low modulus FRPs are more effective on ductility. This shows the importance of separating the confinement stiffness ratio ρ_K and the strain ratio ρ_ε.

4.4.5. Effect of FRP Strength: The range of FRP strength f_{fu} (in the hoop direction) studied was 200 to 4600 MPa. Figs. 12(e) and 13(e) show the variation of f'_{cc} / f'_{co} and ε_{cc} / ε_{co} against f_{fu} for different concrete diameter D (50 to 600 mm), respectively. As shown, increasing the FRP strength increases the confined strength ratio with almost a linear rate; however, the rate drops dramatically for larger diameters. For example, at D=150 mm, increasing f_{fu} from 200 to 4600 MPa resulted in a 179.5% increase in the confined strength ratio (i.e., from 1.12 to 3.14); and at

D=600 mm, it resulted in a 47.9% increase only (i.e., from 1.03 to 1.52). In terms of ratio, at D=150 mm, increasing f_{fu} from 200 to 4600 MPa resulted in a 560.3% increase in the confined strength ratio (i.e., from 1.87 to 12.32); and at D=600 mm, it resulted in a 264.1% increase (i.e., from 1.65 to 6.02). Clearly, stronger FRPs are more effective, especially on improving the ductility of the concrete cylinders.

5. CONCLUSIONS

In this paper, using a large experimental database including 518 experimental data points, the performance of existing confinement models for the ultimate condition of FRP-confined concrete under uniaxial compression loadings was studied. Then, using a general regression analysis improved empirical models with different forms for the axial compressive strength f'_{cc} and the ultimate axial strain ε_{cc} were developed. The performance of the improved models was compared to the existing models using the experimental database and the best forms were proposed for design guidelines and practical applications. The proposed models showed significantly better statistical performance than all existing models. At the end, the proposed models were examined through a parametric study on different material and geometric parameters, namely fiber type, cylinder diameter, concrete strength, and FRP wrap thickness, modulus, and strength. This study has practical value for the engineering community as it presents models that produce less error.

NOTATION

D = diameter of concrete core;

e_i = error for the data point number i;

E_2 = second slope of bilinear stress-strain curve of confined concrete;

E_f = elastic modulus of FRP wrap in hoop direction;

f = errors function;

f'_{cc} = axial compressive strength of confined concrete;

f'_{co} = unconfined concrete strength;

f_l = maximum confinement stress;

f_o = intercept of the second slope with stress axis;

i = data point number;

n = number of data points;

R^2 = coefficient of determination;

$RMSE$ = Root Mean Square Error index;

t = total thickness of FRP wrap;

x = experimental value;

$\bar{x}$ = average of experimental values;

X = vector of experimental values;

y = predicted value;

$\bar{y}$ = average of predicted values;

Y = vector of predicted values;

ε_{cc} = ultimate axial strain of confined concrete at peak strength;

ε_{co} = axial strain of unconfined concrete at peak strength;

$\varepsilon_{h,rup}$ = actual hoop rupture strain of FRP wrap;

k = constant factor;

$\lambda, \lambda_1, \lambda_2$ = constant factors;

μ, μ_1, μ_2 = constant factors;

ρ_K = confinement stiffness ratio; and

ρ_ε = strain ratio;

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Table 1. Experimental database containing 518 cylindrical specimens confined with unidirectional FRP wraps in hoop direction

No.	Source of data	Fiber type	FRP data	D (mm)	t (mm)	f'_{co} (MPa)	f'_{cc} (MPa)	f'_{cc}/f'_{co}	ε_{co} (%)	ε_{cc} (%)	$\varepsilon_{cc}/\varepsilon_{co}$	$\varepsilon_{h,rup}$ (%)	ρ_{ε}	E_f (GPa)	ρ_K	f_l/f'_{co}
1	Watanable et al. [22][a]	C	F	100	0.14	30.2	41.7	1.38	0.22	0.57	2.59	0.23	1.05	612	0.125	0.131
2	Watanable et al. [22][a]	C	F	100	0.28	30.2	56.0	1.85	0.22	0.88	4.01	0.22	1.00	612	0.249	0.250
3	Watanable et al. [22][a]	C	F	100	0.42	30.2	63.3	2.10	0.22	1.30	5.92	0.22	1.00	612	0.374	0.374
4	Matthys et al. [23][a]	C	F	150	0.24	34.9	41.3	1.18	0.23	0.40	1.76	0.19	0.83	420	0.088	0.073
5	Matthys et al. [23][a]	C	F	150	0.24	34.9	40.7	1.17	0.23	0.36	1.58	0.18	0.79	420	0.088	0.069
6	Dias da Silva and Santos [24][a]	C	M	150	0.17	28.2	41.5	1.47	0.22	0.75	3.47	0.37	1.71	390	0.066	0.114
7	Dias da Silva and Santos [24][a]	C	M	150	0.33	28.2	65.6	2.33	0.22	1.81	8.38	0.69	3.20	390	0.133	0.425
8	Dias da Silva and Santos [24][a]	C	M	150	0.50	28.2	79.4	2.82	0.22	1.69	7.83	0.64	2.96	390	0.199	0.591
9	Ozbakkaloglu [25]	C	F	152	0.38	59.0	73.9	1.25	0.26	0.44	1.69	0.12	0.46	640	0.141	0.065
10	Matthys et al. [23][a]	C	F	150	0.12	34.9	44.3	1.27	0.23	0.85	3.73	1.15	5.05	200	0.021	0.105
11	Matthys et al. [23][a]	C	F	150	0.12	34.9	42.2	1.21	0.23	0.72	3.16	1.08	4.74	200	0.021	0.099
12	Watanable et al. [22][a]	C	F	100	0.17	30.2	46.6	1.54	0.22	1.51	6.87	0.94	4.28	225	0.056	0.238
13	Watanable et al. [22][a]	C	F	100	0.50	30.2	87.2	2.89	0.22	3.11	14.16	0.82	3.73	225	0.163	0.610
14	Watanable et al. [22][a]	C	F	100	0.67	30.2	104.6	3.46	0.22	4.15	18.89	0.76	3.46	225	0.219	0.757
15	Matthys et al. [23][b]	C-R	N	400	0.59	37.3	59.4	1.59	0.23	1.12	4.84	0.69	2.98	260	0.047	0.141
16	Matthys et al. [23][b]	C-R	N	400	0.94	37.3	59.4	1.59	0.23	0.43	1.86	0.25	1.08	663	0.193	0.209
17	Rochette and Labossiere [26][a]	C	F	100	0.60	42.0	73.5	1.75	0.24	1.65	6.92	0.89	3.73	83	0.056	0.210
18	Rochette and Labossiere [26][a]	C	F	100	0.60	42.0	73.5	1.75	0.24	1.57	6.58	0.95	3.98	83	0.056	0.224
19	Rochette and Labossiere [26][a]	C	F	100	0.60	42.0	67.6	1.61	0.24	1.35	5.66	0.80	3.35	83	0.056	0.189
20	Xiao and Wu [27][a]	C	F	152	0.38	33.7	47.9	1.42	0.23	1.20	5.32	0.84	3.72	105	0.035	0.131
21	Xiao and Wu [27][a]	C	F	152	0.38	33.7	49.7	1.47	0.23	1.40	6.20	1.15	5.09	105	0.035	0.179
22	Xiao and Wu [27][a]	C	F	152	0.38	33.7	49.4	1.47	0.23	1.24	5.49	0.87	3.85	105	0.035	0.136
23	Xiao and Wu [27][a]	C	F	152	0.76	33.7	64.6	1.92	0.23	1.65	7.31	0.91	4.03	105	0.070	0.284
24	Xiao and Wu [27][a]	C	F	152	0.76	33.7	75.2	2.23	0.23	2.25	9.97	1.00	4.43	105	0.070	0.312
25	Xiao and Wu [27][a]	C	F	152	0.76	33.7	71.8	2.13	0.23	2.16	9.57	1.00	4.43	105	0.070	0.312
26	Xiao and Wu [27][a]	C	F	152	1.14	33.7	82.9	2.46	0.23	2.45	10.85	0.82	3.63	105	0.106	0.383
27	Xiao and Wu [27][a]	C	F	152	1.14	33.7	95.4	2.83	0.23	3.03	13.42	0.90	3.99	105	0.106	0.421
28	Xiao and Wu [27][a]	C	F	152	0.38	43.8	54.8	1.25	0.24	0.98	4.07	0.81	3.36	105	0.029	0.097
29	Xiao and Wu [27][a]	C	F	152	0.38	43.8	52.1	1.19	0.24	0.47	1.95	0.76	3.15	105	0.029	0.091
30	Xiao and Wu [27][a]	C	F	152	0.38	43.8	48.7	1.11	0.24	0.37	1.53	0.28	1.16	105	0.029	0.034

31	Xiao and Wu [27][a]	C	F	152	0.76	43.8	84.0	1.92	0.24	1.57	6.51	0.92	3.82	105	0.058	0.221
32	Xiao and Wu [27][a]	C	F	152	0.76	43.8	79.2	1.81	0.24	1.37	5.68	1.00	4.15	105	0.058	0.240
33	Xiao and Wu [27][a]	C	F	152	0.76	43.8	85.0	1.94	0.24	1.66	6.89	1.01	4.19	105	0.058	0.242
34	Xiao and Wu [27][a]	C	F	152	1.14	43.8	96.5	2.20	0.24	1.74	7.22	0.79	3.28	105	0.087	0.284
35	Xiao and Wu [27][a]	C	F	152	1.14	43.8	92.6	2.11	0.24	1.68	6.97	0.71	2.95	105	0.087	0.255
36	Xiao and Wu [27][a]	C	F	152	1.14	43.8	94.0	2.15	0.24	1.75	7.26	0.84	3.48	105	0.087	0.302
37	Xiao and Wu [27][a]	C	F	152	0.38	55.2	57.9	1.05	0.26	0.69	2.70	0.70	2.74	105	0.024	0.067
38	Xiao and Wu [27][a]	C	F	152	0.38	55.2	62.9	1.14	0.26	0.48	1.88	0.62	2.43	105	0.024	0.059
39	Xiao and Wu [27][a]	C	F	152	0.38	55.2	58.1	1.05	0.26	0.49	1.92	0.19	0.74	105	0.024	0.018
40	Xiao and Wu [27][a]	C	F	152	0.76	55.2	55.2	1.00	0.26	1.21	4.74	0.74	2.90	106	0.049	0.142
41	Xiao and Wu [27][a]	C	F	152	0.76	55.2	77.6	1.41	0.26	0.81	3.17	0.83	3.25	105	0.049	0.158
42	Xiao and Wu [27][a]	C	F	152	1.14	55.2	106.5	1.93	0.26	1.43	5.60	0.76	2.98	105	0.073	0.217
43	Xiao and Wu [27][a]	C	F	152	1.14	55.2	108.0	1.96	0.26	1.45	5.68	0.85	3.33	105	0.073	0.243
44	Xiao and Wu [27][a]	C	F	152	1.14	55.2	103.3	1.87	0.26	1.18	4.62	0.70	2.74	105	0.073	0.200
45	De Lorenzis et al. [28][a]	C	F	120	0.30	43.0	58.5	1.36	0.24	1.16	4.83	0.70	2.92	91	0.025	0.074
46	De Lorenzis et al. [28][a]	C	F	120	0.30	43.0	65.6	1.53	0.24	0.95	3.96	0.80	3.33	91	0.025	0.085
47	De Lorenzis et al. [28][a]	C	F	150	0.45	38.0	62.0	1.63	0.23	0.95	4.08	0.80	3.44	91	0.033	0.115
48	De Lorenzis et al. [28][a]	C	F	150	0.45	38.0	67.3	1.77	0.23	1.35	5.80	0.80	3.44	91	0.033	0.115
49	Picher et al. [29][a]	C	M	152	0.36	39.7	56.0	1.41	0.24	1.07	4.55	0.84	3.57	83	0.023	0.083
50	Purba and Mufti [30][a]	C	M	191	0.22	27.1	53.9	1.99	0.21	0.58	2.69	0.67	3.13	231	0.042	0.131
51	Aire et al. [31][a]	C	M	150	0.12	42.0	46.0	1.10	0.24	1.10	4.61	0.95	3.98	240	0.021	0.085
52	Aire et al. [31][a]	C	M	150	0.35	42.0	77.0	1.83	0.24	2.26	9.47	1.05	4.40	240	0.064	0.281
53	Aire et al. [31][a]	C	M	150	0.70	42.0	108.0	2.57	0.24	3.23	13.54	1.06	4.44	240	0.128	0.567
54	Dias da Silva and Santos [24][a]	C	M	150	0.11	28.2	31.4	1.11	0.22	0.39	1.81	0.26	1.20	240	0.027	0.033
55	Dias da Silva and Santos [24][a]	C	M	150	0.22	28.2	57.4	2.04	0.22	2.05	9.49	1.18	5.46	240	0.054	0.297
56	Dias da Silva and Santos [24][a]	C	M	150	0.33	28.2	69.5	2.46	0.22	2.59	11.99	1.14	5.28	240	0.082	0.431
57	Micelli et al. [32][a]	C	M	102	0.16	37.0	60.0	1.62	0.23	1.02	4.41	1.20	5.19	227	0.044	0.231
58	Micelli et al. [32][a]	C	M	152	1.00	26.2	50.6	1.93	0.21	1.44	6.79	0.81	3.82	38	0.041	0.155
59	Micelli et al. [32][a]	C	M	152	2.00	26.2	64.0	2.44	0.21	1.65	7.78	0.72	3.40	38	0.081	0.276
60	Wang and Cheong [33][a]	C	M	200	0.36	27.9	82.8	2.97	0.22	1.52	7.06	0.85	3.95	235	0.065	0.258
61	Wang and Cheong [33][a]	C	M	200	0.36	27.9	81.2	2.91	0.22	1.43	6.64	1.07	4.97	235	0.065	0.324
62	Shehata et al. [34][a]	C	M	150	0.17	29.8	57.0	1.91	0.22	1.23	5.62	1.23	5.62	235	0.038	0.213
63	Shehata et al. [34][a]	C	M	150	0.33	29.8	72.1	2.42	0.22	1.74	7.95	1.19	5.44	235	0.076	0.413
64	Wang and Wu [35]	C	F	150	0.17	30.9	55.8	1.81	0.22	2.50	11.32	1.11	5.02	219	0.034	0.173
65	Wang and Wu [35]	C	F	150	0.17	52.1	67.9	1.30	0.25	3.36	13.35	1.11	4.41	219	0.023	0.103

66	Wang and Wu [35]	C	F	150	0.33	52.1	99.3	1.91	0.25	2.00	7.94	1.44	5.72	197	0.042	0.240
67	Toutanji [8]	C	F	76	0.22	30.9	95.0	3.07	0.22	2.45	11.09	1.25	5.66	231	0.095	0.539
68	Toutanji [8]	C	F	76	0.33	30.9	94.0	3.04	0.22	1.55	7.01	0.55	2.49	373	0.231	0.576
69	Lam and Teng [36]	C	F	152	0.17	35.9	50.4	1.40	0.23	1.27	5.55	1.15	5.00	259	0.036	0.180
70	Lam and Teng [36]	C	F	152	0.17	35.9	47.2	1.31	0.23	1.11	4.82	0.97	4.22	259	0.036	0.152
71	Lam and Teng [36]	C	F	152	0.17	35.9	53.2	1.48	0.23	1.29	5.63	0.98	4.28	259	0.036	0.154
72	Lam and Teng [36]	C	F	152	0.33	35.9	68.7	1.91	0.23	1.68	7.34	0.99	4.31	259	0.072	0.309
73	Lam and Teng [36]	C	F	152	0.33	35.9	69.9	1.95	0.23	1.96	8.55	1.00	4.36	259	0.072	0.313
74	Lam and Teng [36]	C	F	152	0.33	34.3	71.6	2.09	0.23	1.85	8.16	0.95	4.19	259	0.074	0.311
75	Lam and Teng [36]	C	F	152	0.50	34.3	82.6	2.41	0.23	2.05	9.02	0.80	3.52	259	0.111	0.393
76	Lam and Teng [36]	C	F	152	0.50	34.3	90.4	2.64	0.23	2.41	10.64	0.88	3.90	259	0.111	0.434
77	Lam and Teng [36]	C	F	152	0.50	34.3	97.3	2.84	0.23	2.52	11.10	0.97	4.27	259	0.111	0.476
78	Lam and Teng [36]	C	F	152	0.17	34.3	50.3	1.47	0.23	1.02	4.51	0.91	4.00	259	0.037	0.149
79	Lam and Teng [36]	C	F	152	0.17	34.3	50.0	1.46	0.23	1.08	4.77	0.89	3.92	259	0.037	0.146
80	Lam and Teng [36]	C	F	152	0.17	34.3	56.7	1.65	0.23	1.17	5.15	0.93	4.09	259	0.037	0.152
81	Shahawy et al. [21] [d]	C	M	152	0.50	19.7	33.8	1.72	0.20	1.59	8.05	0.74	3.75	207	0.136	0.512
82	Shahawy et al. [21] [d]	C	M	152	1.00	19.7	46.4	2.36	0.20	2.21	11.20	0.63	3.19	207	0.273	0.871
83	Shahawy et al. [21] [d]	C	M	152	1.50	19.7	62.6	3.18	0.20	2.58	13.07	0.57	2.89	207	0.409	1.182
84	Shahawy et al. [21] [d]	C	M	152	2.00	19.7	75.7	3.84	0.20	3.56	18.03	0.59	2.99	207	0.546	1.631
85	Shahawy et al. [21] [d]	C	M	152	2.50	19.7	80.2	4.07	0.20	3.42	17.32	0.60	3.04	207	0.682	2.074
86	Shahawy et al. [21]	C	M	152	0.50	49.0	59.1	1.21	0.25	0.62	2.50	0.62	2.50	207	0.069	0.172
87	Shahawy et al. [21]	C	M	152	1.00	49.0	76.5	1.56	0.25	0.97	3.91	0.62	2.50	207	0.138	0.345
88	Shahawy et al. [21]	C	M	152	1.50	49.0	98.8	2.02	0.25	1.26	5.08	0.63	2.54	207	0.207	0.525
89	Shahawy et al. [21]	C	M	152	2.00	49.0	112.7	2.30	0.25	1.90	7.66	0.62	2.50	207	0.276	0.689
90	Berthet et al. [37]	C	M	160	0.17	25.0	42.8	1.71	0.21	1.63	7.79	0.96	4.57	230	0.040	0.182
91	Berthet et al. [37]	C	M	160	0.17	25.0	37.8	1.51	0.21	0.93	4.45	0.96	4.60	230	0.040	0.183
92	Berthet et al. [37]	C	M	160	0.17	25.0	45.8	1.83	0.21	1.67	7.99	0.96	4.58	230	0.040	0.182
93	Berthet et al. [37]	C	M	160	0.33	25.0	56.7	2.27	0.21	1.73	8.23	0.90	4.29	230	0.080	0.341
94	Berthet et al. [37]	C	M	160	0.33	25.0	55.2	2.21	0.21	1.58	7.53	0.91	4.35	230	0.080	0.346
95	Berthet et al. [37]	C	M	160	0.33	25.0	56.1	2.24	0.21	1.68	8.02	0.91	4.33	230	0.080	0.345
96	Berthet et al. [37]	C	M	160	0.11	40.1	49.8	1.24	0.24	0.55	2.35	1.02	4.30	230	0.019	0.080
97	Berthet et al. [37]	C	M	160	0.11	40.1	50.8	1.27	0.24	0.66	2.81	0.95	4.04	230	0.019	0.075
98	Berthet et al. [37]	C	M	160	0.11	40.1	48.8	1.22	0.24	0.61	2.58	1.20	5.10	230	0.019	0.095
99	Berthet et al. [37]	C	M	160	0.17	40.1	53.7	1.34	0.24	0.66	2.80	0.88	3.73	230	0.028	0.104
100	Berthet et al. [37]	C	M	160	0.17	40.1	54.7	1.36	0.24	0.62	2.63	0.85	3.62	230	0.028	0.101

101	Berthet et al. [37]	C	M	160	0.17	40.1	51.8	1.29	0.24	0.64	2.71	1.04	4.42	230	0.028	0.123
102	Berthet et al. [37]	C	M	160	0.22	40.1	59.7	1.49	0.24	0.60	2.54	0.79	3.34	230	0.037	0.124
103	Berthet et al. [37]	C	M	160	0.22	40.1	60.7	1.51	0.24	0.69	2.94	0.83	3.52	230	0.037	0.131
104	Berthet et al. [37]	C	M	160	0.22	40.1	60.2	1.50	0.24	0.73	3.10	0.81	3.43	230	0.037	0.128
105	Berthet et al. [37]	C	M	160	0.44	40.1	91.6	2.28	0.24	1.44	6.12	0.92	3.92	230	0.074	0.291
106	Berthet et al. [37]	C	M	160	0.44	40.1	89.6	2.23	0.24	1.36	5.78	0.97	4.10	230	0.074	0.305
107	Berthet et al. [37]	C	M	160	0.44	40.1	86.6	2.16	0.24	1.17	4.95	0.89	3.75	230	0.074	0.279
108	Berthet et al. [37]	C	M	160	0.99	40.1	142.4	3.55	0.24	2.46	10.44	0.99	4.19	230	0.167	0.702
109	Berthet et al. [37]	C	M	160	0.99	40.1	140.4	3.50	0.24	2.39	10.13	1.00	4.25	230	0.167	0.711
110	Berthet et al. [37]	C	M	160	1.32	40.1	166.3	4.15	0.24	2.70	11.45	1.00	4.24	230	0.223	0.945
111	Berthet et al. [37]	C	M	160	0.33	52.0	82.6	1.59	0.25	0.83	3.31	0.93	3.71	230	0.046	0.170
112	Berthet et al. [37]	C	M	160	0.33	52.0	82.8	1.59	0.25	0.70	2.78	0.87	3.44	230	0.046	0.158
113	Berthet et al. [37]	C	M	160	0.33	52.0	82.3	1.58	0.25	0.77	3.04	0.89	3.54	230	0.046	0.163
114	Berthet et al. [37]	C	M	160	0.66	52.0	108.1	2.08	0.25	1.14	4.53	0.67	2.65	230	0.092	0.243
115	Berthet et al. [37]	C	M	160	0.66	52.0	112.0	2.15	0.25	1.12	4.47	0.87	3.46	230	0.092	0.318
116	Berthet et al. [37]	C	M	160	0.66	52.0	107.9	2.08	0.25	1.12	4.46	0.88	3.51	230	0.092	0.322
117	Berthet et al. [37]	C	M	70	0.33	112.6	141.1	1.25	0.31	0.45	1.48	0.71	2.33	230	0.059	0.137
118	Berthet et al. [37]	C	M	70	0.33	112.6	143.1	1.27	0.31	0.49	1.60	0.74	2.42	230	0.059	0.142
119	Berthet et al. [37] [e]	C	M	70	0.82	112.6	189.5	1.68	0.31	0.72	2.37	0.75	2.47	230	0.146	0.361
120	Berthet et al. [37] [e]	C	M	70	0.82	112.6	187.9	1.67	0.31	0.70	2.30	0.73	2.39	230	0.146	0.348
121	Berthet et al. [37]	C	M	70	0.33	169.7	186.4	1.10	0.34	0.67	1.97	0.46	1.36	230	0.043	0.059
122	Berthet et al. [37]	C	M	70	0.99	169.7	296.4	1.75	0.34	1.02	3.00	0.80	2.36	230	0.130	0.306
123	Rousakis and Tepfers [38]	C	M	150	0.17	25.2	41.6	1.65	0.21	1.44	6.86	0.70	3.33	377	0.071	0.237
124	Rousakis and Tepfers [38]	C	M	150	0.17	25.2	38.8	1.54	0.21	1.21	5.76	0.58	2.76	377	0.071	0.197
125	Rousakis and Tepfers [38]	C	M	150	0.17	25.2	44.1	1.75	0.21	1.53	7.29	0.64	3.05	377	0.071	0.217
126	Rousakis and Tepfers [38]	C	M	150	0.34	25.2	60.1	2.38	0.21	1.88	8.96	0.64	3.05	377	0.142	0.434
127	Rousakis and Tepfers [38]	C	M	150	0.34	25.2	55.9	2.22	0.21	2.10	10.00	0.55	2.62	377	0.142	0.373
128	Rousakis and Tepfers [38]	C	M	150	0.34	25.2	61.6	2.44	0.21	2.08	9.91	0.57	2.72	377	0.142	0.387
129	Rousakis and Tepfers [38]	C	M	150	0.51	25.2	67.0	2.66	0.21	2.45	11.67	0.45	2.14	377	0.214	0.458
130	Rousakis and Tepfers [38]	C	M	150	0.51	25.2	67.3	2.67	0.21	2.43	11.57	0.37	1.76	377	0.214	0.376
131	Rousakis and Tepfers [38]	C	M	150	0.51	25.2	70.0	2.78	0.21	2.44	11.62	0.44	2.10	377	0.214	0.448
132	Rousakis and Tepfers [38]	C	M	150	0.17	51.8	78.7	1.52	0.25	0.75	2.98	0.54	2.15	377	0.041	0.089
133	Rousakis and Tepfers [38]	C	M	150	0.17	51.8	72.8	1.41	0.25	0.66	2.63	0.40	1.59	377	0.041	0.066
134	Rousakis and Tepfers [38]	C	M	150	0.17	51.8	79.2	1.53	0.25	0.68	2.71	0.52	2.07	377	0.041	0.086
135	Rousakis and Tepfers [38]	C	M	150	0.34	51.8	95.4	1.84	0.25	1.05	4.18	0.55	2.19	377	0.083	0.181

136	Rousakis and Tepfers [38]	C	M	150	0.34	51.8	90.7	1.75	0.25	1.00	3.98	0.36	1.43	377	0.083	0.119
137	Rousakis and Tepfers [38]	C	M	150	0.34	51.8	90.3	1.74	0.25	1.02	4.06	0.51	2.03	377	0.083	0.168
138	Rousakis and Tepfers [38]	C	M	150	0.51	51.8	110.5	2.13	0.25	1.29	5.13	0.44	1.75	377	0.124	0.218
139	Rousakis and Tepfers [38]	C	M	150	0.51	51.8	103.6	2.00	0.25	1.20	4.77	0.31	1.23	377	0.124	0.153
140	Rousakis and Tepfers [38]	C	M	150	0.51	51.8	117.2	2.26	0.25	1.53	6.09	0.56	2.23	377	0.124	0.277
141	Rousakis and Tepfers [38]	C	M	150	0.85	51.8	112.7	2.18	0.25	1.59	6.33	0.29	1.15	377	0.207	0.239
142	Rousakis and Tepfers [38]	C	M	150	0.85	51.8	126.7	2.45	0.25	1.61	6.40	0.36	1.43	377	0.207	0.297
143	Rousakis and Tepfers [38]	C	M	150	0.85	51.8	137.9	2.66	0.25	1.81	7.20	0.53	2.11	377	0.207	0.437
144	Harmon and Slattery [39][b]	C	N	51	0.09	41.0	86.0	2.10	0.24	1.15	4.85	1.13	4.77	235	0.047	0.226
145	Harmon and Slattery [39][b]	C	N	51	0.18	41.0	120.5	2.94	0.24	1.57	6.62	1.00	4.22	235	0.095	0.402
146	Harmon and Slattery [39][b]	C	N	51	0.34	41.0	158.4	3.86	0.24	2.50	10.54	0.75	3.16	235	0.183	0.580
147	Harmon and Slattery [39][b ,d]	C	N	51	0.69	41.0	241.0	5.88	0.24	3.60	15.18	0.25	1.05	235	0.367	0.387
148	Harmon and Slattery [39][b]	C	N	51	0.18	103.0	131.1	1.27	0.30	1.10	3.69	0.20	0.67	235	0.048	0.032
149	Harmon and Slattery [39][b]	C	N	51	0.34	103.0	193.2	1.88	0.30	2.05	6.87	0.73	2.43	235	0.092	0.223
150	Harmon and Slattery [39][b]	C	N	51	0.69	103.0	303.6	2.95	0.30	3.45	11.56	0.55	1.84	235	0.184	0.339
151	Howie and Karbhari [40][b]	C	N	152	0.33	42.5	44.9	1.06	0.24	1.10	4.58	0.45	1.87	227	0.055	0.104
152	Howie and Karbhari [40][b]	C	N	152	0.66	42.5	59.7	1.40	0.24	1.35	5.65	0.55	2.31	227	0.111	0.256
153	Howie and Karbhari [40][b]	C	N	152	0.99	42.5	77.7	1.83	0.24	2.10	8.76	0.55	2.31	227	0.166	0.385
154	Howie and Karbhari [40][b]	C	N	152	1.32	42.5	89.5	2.11	0.24	2.29	9.56	0.34	1.43	227	0.222	0.317
155	Kono et al. [41][b]	C	N	100	0.17	34.3	61.2	1.78	0.23	0.95	4.18	0.88	3.88	235	0.052	0.201
156	Kono et al. [41][b]	C	N	100	0.17	32.3	59.2	1.83	0.22	1.07	4.79	0.79	3.56	235	0.054	0.193
157	Kono et al. [41][b]	C	N	100	0.33	32.3	80.2	2.48	0.22	1.75	7.83	0.89	3.98	235	0.109	0.432
158	Kono et al. [41][b]	C	N	100	0.50	32.3	88.5	2.74	0.22	1.62	7.25	0.72	3.22	235	0.163	0.525
159	Kono et al. [41][b]	C	N	100	0.17	34.8	54.7	1.57	0.23	0.99	4.35	0.80	3.53	235	0.051	0.181
160	Kono et al. [41][b]	C	N	100	0.33	34.8	82.1	2.36	0.23	2.06	9.05	0.77	3.38	235	0.103	0.347
161	Kono et al. [41][b]	C	N	100	0.50	34.8	106.7	3.07	0.23	2.43	10.66	0.85	3.76	235	0.154	0.578
162	Toutanji and Deng [42][b, e]	C	N	76	0.57	31.8	140.9	4.43	0.22	2.05	9.21	1.55	6.95	118	0.124	0.863
163	Toutanji and Deng [42][b]	C	N	76	0.24	31.8	60.8	1.91	0.22	1.53	6.88	1.62	7.30	73	0.032	0.230
164	Toutanji and Deng [42][b]	C	N	76	0.22	31.8	95.0	2.99	0.22	2.45	11.01	1.26	5.66	231	0.093	0.529
165	Toutanji and Deng [42][b]	C	N	76	0.33	31.8	94.0	2.96	0.22	1.55	6.97	0.54	2.44	373	0.227	0.552
166	Youseff [43][b]	C	N	406	1.17	29.4	45.9	1.56	0.22	0.63	2.89	0.82	3.74	105	0.045	0.168
167	Youseff [43][b]	C	N	406	2.34	29.4	64.8	2.20	0.22	1.16	5.29	1.21	5.53	105	0.090	0.497
168	Youseff [43][b]	C	N	406	3.51	29.4	85.9	2.92	0.22	1.56	7.13	1.20	5.51	105	0.135	0.742
169	Youseff [43][b]	C	N	406	5.84	29.4	126.4	4.29	0.22	2.84	13.03	1.24	5.68	105	0.224	1.275
170	Youseff [43][b]	C	N	153	0.58	44.1	86.1	1.95	0.24	1.90	7.88	1.03	4.26	105	0.044	0.186

171	Youseff [43][b]	C	N	153	1.17	44.1	96.6	2.19	0.24	1.99	8.24	1.26	5.22	105	0.088	0.459
172	Youseff [43][b]	C	N	153	1.75	44.1	130.7	2.96	0.24	2.83	11.71	0.97	4.01	105	0.132	0.528
173	Youseff [43][b]	C-R	N	406	2.34	45.6	79.5	1.74	0.24	1.68	6.90	0.89	3.66	105	0.065	0.237
174	Youseff [43][b]	C-R	N	406	2.34	38.3	73.1	1.91	0.23	1.05	4.52	0.96	4.13	105	0.074	0.305
175	Carey and Harries [14][44][b]	C	N	152	0.20	33.5	47.0	1.40	0.23	0.97	4.30	1.07	4.77	250	0.044	0.211
176	Carey and Harries [14][44][b]	C	N	152	0.20	33.5	47.6	1.42	0.23	0.88	3.92	1.14	5.04	250	0.044	0.223
177	Carey and Harries [14][44][b]	C	N	254	1.00	38.9	54.2	1.39	0.23	0.99	4.23	0.51	2.17	73	0.034	0.075
178	Carey and Harries [14][44][b]	C	N	153	0.10	32.1	32.9	1.02	0.22	0.60	2.69	0.82	3.69	250	0.023	0.084
179	Carey and Harries [14][44][b]	C	N	153	0.20	32.1	41.7	1.30	0.22	0.86	3.86	1.04	4.68	250	0.045	0.212
180	Carey and Harries [14][44][b]	C	N	153	0.30	32.1	52.2	1.63	0.22	1.38	6.19	1.23	5.51	250	0.068	0.376
181	Bullo [45][c]	C	N	150	0.17	32.5	52.6	1.62	0.22	0.83	3.71	0.47	2.10	390	0.061	0.128
182	Bullo [45][c]	C	N	150	0.17	32.5	56.6	1.74	0.22	0.93	4.16	0.52	2.34	390	0.061	0.142
183	Bullo [45][c]	C	N	150	0.17	32.5	61.1	1.88	0.22	0.83	3.71	0.42	1.89	390	0.061	0.115
184	Bullo [45][c]	C	N	150	0.50	32.5	97.3	2.99	0.22	1.82	8.13	0.64	2.86	390	0.179	0.511
185	Bullo [45][c]	C	N	150	0.50	32.5	83.8	2.57	0.22	1.27	5.67	0.44	1.96	390	0.179	0.351
186	Bullo [45][c]	C	N	150	0.50	32.5	100.2	3.08	0.22	1.69	7.55	0.54	2.41	390	0.179	0.431
187	Demers and Neale [46][c]	C	M	152	1.00	43.7	48.4	1.11	0.24	0.97	4.03	1.28	5.29	25	0.018	0.096
188	Demers and Neale [46][c]	C	M	152	3.00	43.7	75.2	1.72	0.24	1.83	7.60	1.07	4.42	25	0.054	0.241
189	Demers and Neale [46][c]	C	M	152	3.00	43.7	73.4	1.68	0.24	1.83	7.60	1.19	4.92	25	0.054	0.268
190	Demers and Neale [46][c]	C	M	152	1.00	32.2	41.1	1.28	0.22	1.41	6.32	1.37	6.12	25	0.023	0.139
191	Jiang and Teng [47]	C	F	152	0.68	38.0	110.1	2.90	0.23	2.55	10.97	0.98	4.20	241	0.132	0.554
192	Jiang and Teng [47]	C	F	152	0.68	38.0	107.4	2.83	0.23	2.61	11.23	0.97	4.15	241	0.132	0.547
193	Jiang and Teng [47]	C	F	152	1.02	38.0	129.0	3.39	0.23	2.79	12.01	0.89	3.83	241	0.198	0.758
194	Jiang and Teng [47]	C	F	152	1.02	38.0	135.7	3.57	0.23	3.08	13.25	0.93	3.98	241	0.198	0.788
195	Jiang and Teng [47]	C	F	152	1.36	38.0	161.3	4.24	0.23	3.70	15.90	0.87	3.75	241	0.264	0.988
196	Jiang and Teng [47]	C	F	152	1.36	38.0	158.5	4.17	0.23	3.54	15.23	0.88	3.77	241	0.264	0.994
197	Jiang and Teng [47]	C	F	152	0.11	37.7	48.5	1.29	0.23	0.90	3.85	0.94	4.03	260	0.023	0.093
198	Jiang and Teng [47]	C	F	152	0.11	37.7	50.3	1.33	0.23	0.91	3.94	1.09	4.70	260	0.023	0.109
199	Jiang and Teng [47]	C	F	152	0.11	44.2	48.1	1.09	0.24	0.69	2.86	0.73	3.04	260	0.021	0.062
200	Jiang and Teng [47]	C	F	152	0.11	44.2	51.1	1.16	0.24	0.89	3.68	0.97	4.01	260	0.021	0.083
201	Jiang and Teng [47]	C	F	152	0.22	44.2	65.7	1.49	0.24	1.30	5.40	1.18	4.90	260	0.041	0.202
202	Jiang and Teng [47]	C	F	152	0.22	44.2	62.9	1.42	0.24	1.03	4.24	0.94	3.88	260	0.041	0.160
203	Jiang and Teng [47]	C	F	152	0.33	47.6	82.7	1.74	0.25	1.30	5.30	0.90	3.66	260	0.058	0.214
204	Jiang and Teng [47]	C	F	152	0.33	47.6	85.5	1.80	0.25	1.94	7.87	1.13	4.59	260	0.058	0.268
205	Jiang and Teng [47]	C	F	152	0.33	47.6	85.5	1.80	0.25	1.82	7.40	1.06	4.32	260	0.058	0.252

206	Lam et al. [48]	C	F	152	0.17	41.1	52.6	1.28	0.24	0.90	3.79	0.81	3.41	250	0.031	0.107
207	Lam et al. [48]	C	F	152	0.17	41.1	57.0	1.39	0.24	1.21	5.10	1.08	4.55	250	0.031	0.143
208	Lam et al. [48]	C	F	152	0.17	41.1	55.4	1.35	0.24	1.11	4.68	1.07	4.51	250	0.031	0.141
209	Lam et al. [48]	C	F	152	0.17	41.1	60.2	1.46	0.24	1.34	5.65	1.32	5.56	250	0.031	0.174
210	Lam et al. [48]	C	F	152	0.17	41.1	56.8	1.38	0.24	1.17	4.93	1.03	4.34	250	0.031	0.136
211	Lam et al. [48]	C	F	152	0.17	41.1	56.5	1.37	0.24	1.20	5.06	1.13	4.76	250	0.031	0.149
212	Lam et al. [48]	C	F	152	0.33	38.9	76.8	1.97	0.23	1.91	8.16	1.06	4.53	250	0.065	0.296
213	Lam et al. [48]	C	F	152	0.33	38.9	79.1	2.03	0.23	2.08	8.89	1.13	4.83	250	0.065	0.315
214	Lam et al. [48]	C	F	152	0.33	38.9	65.8	1.69	0.23	1.25	5.34	0.79	3.38	250	0.065	0.220
215	Lam et al. [48]	C	F	152	0.33	38.9	81.5	2.10	0.23	2.44	10.43	1.22	5.21	250	0.065	0.340
216	Lam et al. [48]	C	F	152	0.33	38.9	78.2	2.01	0.23	1.89	8.08	1.08	4.62	250	0.065	0.301
217	Lam et al. [48]	C	F	152	0.33	38.9	85.6	2.20	0.23	2.34	10.00	1.22	5.21	250	0.065	0.340
218	Modarelli et al. [49][c]	C	N	150	0.17	28.0	55.3	1.97	0.22	0.90	4.18	1.53	7.08	221	0.039	0.273
219	Modarelli et al. [49][c, e]	C	N	150	0.17	38.0	62.7	1.65	0.23	0.48	2.06	1.32	5.66	221	0.031	0.173
220	Cui and Sheikh [50]	C	F	152	1.00	48.1	80.9	1.68	0.25	1.51	6.12	1.05	4.26	85	0.057	0.243
221	Cui and Sheikh [50]	C	F	152	1.00	48.1	86.6	1.80	0.25	1.53	6.20	1.12	4.56	85	0.057	0.260
222	Cui and Sheikh [50]	C	F	152	2.00	48.1	109.4	2.27	0.25	2.01	8.15	0.97	3.92	85	0.114	0.448
223	Cui and Sheikh [50]	C	F	152	2.00	48.1	126.7	2.63	0.25	2.66	10.78	1.22	4.95	85	0.114	0.565
224	Cui and Sheikh [50]	C	F	152	3.00	48.1	162.7	3.38	0.25	3.09	12.52	1.16	4.69	85	0.171	0.804
225	Cui and Sheikh [50]	C	F	152	3.00	48.1	153.6	3.19	0.25	2.89	11.71	1.04	4.19	85	0.171	0.719
226	Cui and Sheikh [50]	C	F	152	1.00	48.1	84.2	1.75	0.25	1.55	6.28	1.05	4.24	85	0.057	0.242
227	Cui and Sheikh [50]	C	F	152	1.00	48.1	87.9	1.83	0.25	1.69	6.85	1.22	4.93	85	0.057	0.281
228	Cui and Sheikh [50]	C	F	152	2.00	48.1	123.3	2.56	0.25	2.37	9.60	1.06	4.30	85	0.114	0.492
229	Cui and Sheikh [50]	C	F	152	2.00	48.1	108.2	2.25	0.25	1.93	7.82	0.89	3.61	85	0.114	0.412
230	Cui and Sheikh [50]	C	F	152	3.00	48.1	156.5	3.25	0.25	3.13	12.68	1.09	4.41	85	0.171	0.756
231	Cui and Sheikh [50]	C	F	152	3.00	48.1	157.0	3.26	0.25	2.84	11.51	1.14	4.60	85	0.171	0.789
232	Cui and Sheikh [50]	C	F	152	1.00	79.9	90.9	1.14	0.28	0.53	1.87	1.10	3.92	85	0.039	0.153
233	Cui and Sheikh [50]	C	F	152	1.00	79.9	105.3	1.32	0.28	0.74	2.64	0.92	3.27	85	0.039	0.128
234	Cui and Sheikh [50]	C	F	152	2.00	79.9	142.1	1.78	0.28	1.13	4.02	0.99	3.52	85	0.078	0.274
235	Cui and Sheikh [50]	C	F	152	2.00	79.9	140.8	1.76	0.28	0.97	3.48	1.10	3.92	85	0.078	0.306
236	Cui and Sheikh [50]	C	F	152	3.00	79.9	172.9	2.16	0.28	1.48	5.28	0.98	3.48	85	0.117	0.408
237	Cui and Sheikh [50]	C	F	152	3.00	79.9	181.8	2.28	0.28	1.47	5.26	1.11	3.97	85	0.117	0.465
238	Cui and Sheikh [50]	C	F	152	1.00	110.6	107.3	0.97	0.30	0.52	1.70	1.03	3.39	85	0.031	0.104
239	Cui and Sheikh [50]	C	F	152	1.00	110.6	116.6	1.05	0.30	0.55	1.81	0.86	2.81	85	0.031	0.086
240	Cui and Sheikh [50]	C	F	152	3.00	110.6	198.4	1.79	0.30	0.84	2.77	0.87	2.85	85	0.092	0.262

241	Cui and Sheikh [50]	C	F	152	3.00	110.6	182.3	1.65	0.30	0.73	2.40	0.75	2.46	85	0.092	0.225
242	Cui and Sheikh [50]	C	F	152	0.11	45.6	57.7	1.27	0.24	1.21	4.97	1.68	6.89	241	0.019	0.130
243	Cui and Sheikh [50]	C	F	152	0.11	45.6	55.4	1.21	0.24	1.31	5.38	1.60	6.57	241	0.019	0.124
244	Cui and Sheikh [50]	C	F	152	0.22	45.6	78.0	1.71	0.24	1.97	8.09	1.62	6.64	241	0.038	0.250
245	Cui and Sheikh [50]	C	F	152	0.22	45.6	86.8	1.90	0.24	2.14	8.79	1.80	7.40	241	0.038	0.278
246	Cui and Sheikh [50]	C	F	152	0.33	45.6	106.5	2.34	0.24	2.90	11.91	1.79	7.34	241	0.056	0.414
247	Cui and Sheikh [50]	C	F	152	0.33	45.6	106.0	2.32	0.24	2.83	11.62	1.80	7.38	241	0.056	0.417
248	Cui and Sheikh [50]	C	F	152	0.11	45.6	56.3	1.23	0.24	1.23	5.05	1.57	6.46	241	0.019	0.122
249	Cui and Sheikh [50]	C	F	152	0.11	45.6	58.8	1.29	0.24	1.19	4.89	1.58	6.51	241	0.019	0.122
250	Cui and Sheikh [50]	C	F	152	0.22	45.6	81.9	1.80	0.24	1.87	7.68	1.03	4.22	241	0.038	0.159
251	Cui and Sheikh [50]	C	F	152	0.22	45.6	82.8	1.82	0.24	2.17	8.91	1.14	4.69	241	0.038	0.177
252	Cui and Sheikh [50]	C	F	152	0.33	45.6	107.3	2.35	0.24	2.86	11.75	1.15	4.73	241	0.056	0.267
253	Cui and Sheikh [50]	C	F	152	0.33	45.6	108.6	2.38	0.24	2.78	11.42	1.15	4.71	241	0.056	0.266
254	Cui and Sheikh [50]	C	F	152	0.11	85.6	64.4	0.75	0.29	0.44	1.55	0.82	2.89	241	0.012	0.034
255	Cui and Sheikh [50]	C	F	152	0.11	85.6	66.6	0.78	0.29	0.44	1.53	0.76	2.66	241	0.012	0.031
256	Cui and Sheikh [50]	C	F	152	0.22	85.6	78.9	0.92	0.29	0.56	1.96	0.74	2.58	241	0.023	0.061
257	Cui and Sheikh [50]	C	F	152	0.22	85.6	86.1	1.01	0.29	0.58	2.04	0.76	2.68	241	0.023	0.063
258	Cui and Sheikh [50]	C	F	152	0.44	85.6	125.4	1.46	0.29	1.00	3.49	0.89	3.11	241	0.047	0.146
259	Cui and Sheikh [50]	C	F	152	0.44	85.6	126.5	1.48	0.29	0.99	3.48	0.92	3.24	241	0.047	0.152
260	Cui and Sheikh [50]	C	F	152	0.22	111.8	101.1	0.90	0.30	0.32	1.06	0.94	3.08	241	0.019	0.059
261	Cui and Sheikh [50]	C	F	152	0.22	111.8	94.3	0.84	0.30	0.48	1.58	0.83	2.71	241	0.019	0.052
262	Cui and Sheikh [50][e]	C	F	152	0.56	111.8	152.1	1.36	0.30	0.50	1.63	0.75	2.47	241	0.048	0.119
263	Cui and Sheikh [50]	C	F	152	0.56	111.8	145.3	1.30	0.30	0.58	1.90	0.60	1.96	241	0.048	0.094
264	Cui and Sheikh [50]	C	F	152	0.16	45.7	67.5	1.48	0.24	1.11	4.56	0.79	3.24	438	0.050	0.162
265	Cui and Sheikh [50]	C	F	152	0.16	45.7	64.1	1.40	0.24	1.03	4.23	0.77	3.16	438	0.050	0.158
266	Cui and Sheikh [50]	C	F	152	0.33	45.7	84.2	1.84	0.24	1.33	5.46	0.64	2.64	438	0.100	0.264
267	Cui and Sheikh [50]	C	F	152	0.33	45.7	83.1	1.82	0.24	1.23	5.05	0.63	2.60	438	0.100	0.260
268	Cui and Sheikh [50]	C	F	152	0.49	45.7	99.7	2.18	0.24	1.56	6.40	0.60	2.48	438	0.150	0.371
269	Cui and Sheikh [50]	C	F	152	0.49	45.7	94.9	2.08	0.24	1.43	5.87	0.55	2.24	438	0.150	0.336
270	Cui and Sheikh [50]	C	F	152	0.16	45.7	65.8	1.44	0.24	0.97	3.98	0.72	2.94	438	0.050	0.147
271	Cui and Sheikh [50]	C	F	152	0.16	45.7	65.9	1.44	0.24	1.03	4.23	0.77	3.16	438	0.050	0.158
272	Cui and Sheikh [50]	C	F	152	0.33	45.7	88.1	1.93	0.24	1.42	5.83	0.69	2.84	438	0.100	0.284
273	Cui and Sheikh [50]	C	F	152	0.33	45.7	82.0	1.79	0.24	1.23	5.05	0.61	2.50	438	0.100	0.250
274	Cui and Sheikh [50]	C	F	152	0.65	45.7	103.2	2.26	0.24	1.53	6.28	0.36	1.49	438	0.200	0.297
275	Cui and Sheikh [50]	C	F	152	0.65	45.7	105.6	2.31	0.24	1.86	7.63	0.44	1.79	438	0.200	0.359

276	Cui and Sheikh [50]	C	F	152	0.16	85.7	91.5	1.07	0.29	0.42	1.48	0.30	1.06	438	0.031	0.033
277	Cui and Sheikh [50]	C	F	152	0.16	85.7	94.5	1.10	0.29	0.54	1.90	0.42	1.46	438	0.031	0.046
278	Cui and Sheikh [50]	C	F	152	0.33	85.7	117.7	1.37	0.29	0.71	2.48	0.44	1.53	438	0.062	0.095
279	Cui and Sheikh [50]	C	F	152	0.33	85.7	117.5	1.37	0.29	0.55	1.94	0.41	1.44	438	0.062	0.090
280	Cui and Sheikh [50]	C	F	152	0.65	85.7	161.6	1.89	0.29	1.02	3.57	0.38	1.34	438	0.125	0.168
281	Cui and Sheikh [50]	C	F	152	0.65	85.7	162.6	1.90	0.29	0.95	3.34	0.38	1.32	438	0.125	0.165
282	Cui and Sheikh [50][e]	C	F	152	0.33	111.8	139.1	1.24	0.30	0.32	1.06	0.22	0.73	438	0.051	0.037
283	Cui and Sheikh [50]	C	F	152	0.33	111.8	123.3	1.10	0.30	0.31	1.03	0.17	0.55	438	0.051	0.028
284	Cui and Sheikh [50]	C	F	152	0.82	111.8	176.4	1.58	0.30	0.49	1.60	0.24	0.79	438	0.128	0.102
285	Cui and Sheikh [50]	C	F	152	0.82	111.8	172.5	1.54	0.30	0.50	1.64	0.21	0.68	438	0.128	0.087
286	Smith et al. [51]	C	F	250	0.26	35.0	43.0	1.23	0.23	0.36	1.58	0.69	3.04	211	0.029	0.087
287	Smith et al. [51][e]	C	F	250	0.26	35.0	50.0	1.43	0.23	0.42	1.84	0.89	3.92	211	0.029	0.113
288	Smith et al. [51]	C	F	250	0.26	35.0	57.0	1.63	0.23	0.68	2.98	1.22	5.34	211	0.029	0.154
289	Smith et al. [51][e]	C	F	250	0.26	35.0	59.0	1.69	0.23	0.54	2.37	1.31	5.75	211	0.029	0.165
290	Smith et al. [51][e]	C	F	250	0.26	35.0	56.0	1.60	0.23	0.45	1.97	1.15	5.04	211	0.029	0.145
291	Benzaid et al. [52]	C	F	160	1.00	29.5	50.6	1.71	0.22	1.59	7.29	1.32	6.02	34	0.031	0.189
292	Benzaid et al. [52]	C	F	160	1.00	29.5	49.2	1.67	0.22	1.48	6.75	1.32	6.03	34	0.031	0.190
293	Benzaid et al. [52]	C	F	160	3.00	29.5	70.8	2.40	0.22	2.22	10.17	1.41	6.44	34	0.094	0.607
294	Benzaid et al. [52]	C	F	160	3.00	29.5	71.9	2.44	0.22	2.37	10.87	1.24	5.69	34	0.094	0.537
295	Benzaid et al. [52]	C	F	160	1.00	25.9	39.6	1.53	0.21	1.28	6.04	1.31	6.21	34	0.035	0.215
296	Benzaid et al. [52]	C	F	160	3.00	25.9	66.1	2.55	0.21	1.52	7.17	1.32	6.23	34	0.104	0.648
297	Benzaid et al. [52]	C	F	160	1.00	58.2	75.8	1.30	0.26	0.74	2.85	1.32	5.09	34	0.019	0.096
298	Benzaid et al. [52]	C	F	160	1.00	58.2	79.2	1.36	0.26	0.94	3.61	1.32	5.08	34	0.019	0.096
299	Benzaid et al. [52]	C	F	160	3.00	58.2	101.5	1.74	0.26	1.37	5.30	1.32	5.10	34	0.057	0.289
300	Benzaid et al. [52]	C	F	160	3.00	58.2	99.4	1.71	0.26	1.34	5.19	1.32	5.09	34	0.057	0.288
301	Benzaid et al. [52]	C	F	160	1.00	49.5	52.8	1.07	0.25	0.25	1.01	0.29	1.17	34	0.021	0.025
302	Benzaid et al. [52]	C	F	160	3.00	49.5	82.9	1.68	0.25	0.73	2.93	1.32	5.29	34	0.064	0.339
303	Benzaid et al. [52]	C	F	160	1.00	63.0	78.0	1.24	0.26	0.46	1.74	0.78	2.95	34	0.018	0.053
304	Benzaid et al. [52]	C	F	160	1.00	63.0	74.4	1.18	0.26	0.29	1.10	0.26	0.99	34	0.018	0.018
305	Benzaid et al. [52]	C	F	160	3.00	63.0	94.9	1.51	0.26	0.39	1.47	0.41	1.55	34	0.053	0.083
306	Benzaid et al. [52]	C	F	160	3.00	63.0	94.7	1.50	0.26	0.85	3.22	0.72	2.71	34	0.053	0.145
307	Benzaid et al. [52]	C	F	160	1.00	61.8	62.7	1.01	0.26	0.33	1.24	0.25	0.94	34	0.018	0.017
308	Benzaid et al. [52]	C	F	160	3.00	61.8	93.2	1.51	0.26	1.05	4.01	1.29	4.91	34	0.054	0.266
309	Wang et al. [53]	C	F	305	0.17	24.5	35.0	1.43	0.21	1.85	8.87	1.60	7.68	244	0.023	0.175
310	Wang et al. [53]	C	F	305	0.33	24.5	55.3	2.26	0.21	3.26	15.61	1.62	7.75	244	0.045	0.352

311	Wang et al. [53]	C-R	F	305	0.17	24.5	41.5	1.69	0.21	1.82	8.75	1.43	6.86	244	0.023	0.156
312	Wang et al. [53]	C-R	F	305	0.17	24.5	43.1	1.76	0.21	1.96	9.41	1.45	6.94	244	0.023	0.158
313	Wang et al. [53]	C-R	F	305	0.33	24.5	52.2	2.13	0.21	2.68	12.87	1.25	5.99	244	0.045	0.272
314	Wang et al. [53]	C-R	F	305	0.33	24.5	61.8	2.52	0.21	3.22	15.46	1.55	7.45	244	0.045	0.339
315	Wang et al. [53]	C-R	F	305	0.17	24.5	47.0	1.92	0.21	2.32	11.11	1.40	6.71	244	0.023	0.152
316	Wang et al. [53]	C-R	F	305	0.33	24.5	62.1	2.53	0.21	3.30	15.82	1.52	7.29	244	0.045	0.332
317	Wang et al. [53]	C	F	204	0.17	24.5	46.1	1.88	0.21	2.45	11.75	1.68	8.05	244	0.034	0.274
318	Wang et al. [53]	C	F	204	0.17	24.5	42.3	1.73	0.21	1.94	9.30	1.47	7.05	244	0.034	0.240
319	Wang et al. [53]	C	F	204	0.17	24.5	46.5	1.90	0.21	2.40	11.51	1.40	6.71	244	0.034	0.228
320	Wang et al. [53]	C	F	204	0.33	24.5	65.2	2.66	0.21	3.66	17.53	1.45	6.97	244	0.068	0.474
321	Wang et al. [53]	C	F	204	0.33	24.5	66.8	2.73	0.21	3.82	18.31	1.36	6.51	244	0.068	0.443
322	Wang et al. [53]	C	F	204	0.33	24.5	64.6	2.64	0.21	3.41	16.34	1.09	5.20	244	0.068	0.354
323	Wang et al. [53]	C-R	F	204	0.17	24.5	52.1	2.13	0.21	2.31	11.06	1.39	6.65	244	0.034	0.226
324	Wang et al. [53]	C-R	F	204	0.17	24.5	49.9	2.04	0.21	2.38	11.43	1.53	7.36	244	0.034	0.250
325	Wang et al. [53]	C-R	F	204	0.17	24.5	45.6	1.86	0.21	1.73	8.30	1.18	5.67	244	0.034	0.193
326	Wang et al. [53]	C-R	F	204	0.17	24.5	54.5	2.22	0.21	2.72	13.02	1.31	6.27	244	0.034	0.213
327	Wang et al. [53]	C-R	F	204	0.33	24.5	66.1	2.70	0.21	3.41	16.36	1.31	6.26	244	0.068	0.426
328	Wang et al. [53]	C-R	F	204	0.33	24.5	68.9	2.81	0.21	3.39	16.28	1.33	6.37	244	0.068	0.433
329	Wang et al. [53]	C-R	F	204	0.33	24.5	67.4	2.75	0.21	3.19	15.32	1.52	7.30	244	0.068	0.496
330	Wang et al. [53]	C-R	F	204	0.33	24.5	77.4	3.16	0.21	3.89	18.67	1.74	8.34	244	0.068	0.567
331	Wang et al. [53]	C-R	F	204	0.17	24.5	52.2	2.13	0.21	2.54	12.16	1.31	6.26	244	0.034	0.213
332	Wang et al. [53]	C-R	F	204	0.17	24.5	57.0	2.33	0.21	2.81	13.46	1.50	7.21	244	0.034	0.245
333	Wang et al. [53]	C-R	F	204	0.33	24.5	69.5	2.84	0.21	3.41	16.34	1.30	6.23	244	0.068	0.423
334	Wang et al. [53]	C-R	F	204	0.33	24.5	75.0	3.06	0.21	4.03	19.35	1.54	7.38	244	0.068	0.502
335	Abdelrahman and El-Hacha [54]	C	M	300	0.38	40.1	51.0	1.27	0.24	0.23	0.98	0.44	1.86	65	0.010	0.018
336	Abdelrahman and El-Hacha [54]	C-R	M	300	0.38	38.3	72.0	1.88	0.23	0.41	1.76	0.94	4.05	65	0.010	0.041
337	Marques and Chastre [55]	C-R	F	150	0.33	38.0	84.1	2.21	0.23	1.31	5.63	0.90	3.87	226	0.062	0.238
338	Marques and Chastre [55]	C-R	F	250	0.35	35.2	76.2	2.17	0.23	1.55	6.79	0.93	4.07	241	0.044	0.179
339	Marques and Chastre [55]	C-R	F	400	0.59	34.3	59.4	1.73	0.23	1.15	5.07	0.73	3.22	198	0.038	0.123
340	Micelli and Modarelli [56]	C	F	150	0.17	28.4	55.3	1.95	0.22	2.20	10.18	1.53	7.08	221	0.037	0.262
341	Micelli and Modarelli [56]	C-H	F	150	0.17	28.4	45.2	1.59	0.22	2.25	10.41	1.22	5.64	221	0.037	0.209
342	Micelli and Modarelli [56]	C-H	F	150	0.33	28.4	50.8	1.79	0.22	2.55	11.79	0.65	3.01	221	0.074	0.223
343	Micelli and Modarelli [56]	C-H	F	150	0.50	28.4	80.0	2.82	0.22	3.09	14.29	0.73	3.38	221	0.111	0.376
344	Micelli and Modarelli [56]	C	F	150	0.17	38.2	62.7	1.64	0.23	1.49	6.39	1.32	5.67	221	0.030	0.168
345	Micelli and Modarelli [56]	C-H	F	150	0.17	38.2	47.9	1.25	0.23	1.53	6.57	1.23	5.28	221	0.030	0.156

346	Micelli and Modarelli [56]	C-H	F	150	0.33	38.2	59.2	1.55	0.23	1.71	7.34	0.77	3.30	221	0.059	0.196
347	Wu and Jiang [57]	C	F	150	0.17	20.6	50.4	2.45	0.20	1.97	9.87	1.41	7.07	242	0.052	0.369
348	Wu and Jiang [57]	C	F	150	0.17	20.6	53.0	2.57	0.20	2.14	10.72	1.56	7.82	242	0.052	0.409
349	Wu and Jiang [57]	C	F	150	0.17	20.6	53.2	2.59	0.20	2.27	11.38	1.43	7.17	242	0.052	0.375
350	Wu and Jiang [57]	C	F	150	0.33	20.6	83.7	4.07	0.20	3.86	19.34	1.84	9.22	242	0.105	0.964
351	Wu and Jiang [57]	C	F	150	0.33	20.6	86.6	4.21	0.20	4.02	20.15	1.86	9.32	242	0.105	0.974
352	Wu and Jiang [57]	C	F	150	0.33	20.6	88.8	4.32	0.20	2.97	14.88	2.26	11.33	242	0.105	1.184
353	Wu and Jiang [57]	C	F	150	0.50	20.6	110.2	5.36	0.20	4.82	24.15	1.79	8.97	242	0.157	1.407
354	Wu and Jiang [57]	C	F	150	0.50	20.6	108.1	5.26	0.20	4.86	24.35	1.37	6.87	242	0.157	1.077
355	Wu and Jiang [57]	C	F	150	0.50	20.6	110.0	5.35	0.20	4.13	20.70	1.73	8.67	242	0.157	1.360
356	Wu and Jiang [57]	C	F	150	0.67	20.6	127.7	6.21	0.20	5.49	27.51	1.92	9.62	242	0.209	2.012
357	Wu and Jiang [57]	C	F	150	0.67	20.6	132.5	6.44	0.20	5.52	27.66	1.85	9.27	242	0.209	1.939
358	Wu and Jiang [57]	C	F	150	0.67	20.6	140.6	6.83	0.20	5.20	26.06	1.71	8.57	242	0.209	1.792
359	Wu and Jiang [57]	C	F	150	0.17	24.8	61.7	2.49	0.21	2.21	10.57	1.81	8.66	242	0.045	0.393
360	Wu and Jiang [57]	C	F	150	0.17	24.8	56.7	2.29	0.21	2.02	9.66	1.56	7.46	242	0.045	0.339
361	Wu and Jiang [57]	C	F	150	0.17	24.8	56.9	2.29	0.21	2.13	10.19	2.04	9.76	242	0.045	0.443
362	Wu and Jiang [57]	C	F	150	0.33	24.8	87.2	3.52	0.21	3.45	16.50	1.87	8.94	242	0.091	0.813
363	Wu and Jiang [57]	C	F	150	0.33	24.8	87.8	3.54	0.21	3.61	17.26	1.71	8.18	242	0.091	0.743
364	Wu and Jiang [57]	C	F	150	0.33	24.8	88.3	3.56	0.21	3.52	16.83	1.65	7.89	242	0.091	0.717
365	Wu and Jiang [57]	C	F	150	0.50	24.8	118.6	4.78	0.21	4.08	19.51	1.73	8.27	242	0.136	1.128
366	Wu and Jiang [57]	C	F	150	0.50	24.8	114.7	4.62	0.21	4.36	20.85	1.75	8.37	242	0.136	1.141
367	Wu and Jiang [57]	C	F	150	0.50	24.8	114.6	4.62	0.21	4.19	20.04	2.00	9.56	242	0.136	1.304
368	Wu and Jiang [57]	C	F	150	0.67	24.8	133.8	5.39	0.21	5.09	24.34	1.36	6.50	242	0.182	1.182
369	Wu and Jiang [57]	C	F	150	0.67	24.8	135.0	5.44	0.21	4.95	23.67	1.44	6.89	242	0.182	1.252
370	Wu and Jiang [57]	C	F	150	0.67	24.8	139.1	5.61	0.21	4.96	23.72	1.51	7.22	242	0.182	1.312
371	Wu and Jiang [57]	C	F	150	0.17	36.7	61.9	1.69	0.23	1.58	6.85	1.52	6.59	242	0.034	0.223
372	Wu and Jiang [57]	C	F	150	0.17	36.7	71.6	1.95	0.23	2.02	8.76	1.91	8.28	242	0.034	0.281
373	Wu and Jiang [57]	C	F	150	0.17	36.7	65.5	1.79	0.23	1.63	7.07	1.60	6.94	242	0.034	0.235
374	Wu and Jiang [57]	C	F	150	0.33	36.7	92.4	2.52	0.23	2.72	11.80	1.60	6.94	242	0.068	0.470
375	Wu and Jiang [57]	C	F	150	0.33	36.7	97.6	2.66	0.23	2.79	12.10	1.68	7.29	242	0.068	0.494
376	Wu and Jiang [57]	C	F	150	0.33	36.7	95.7	2.61	0.23	2.90	12.58	1.71	7.42	242	0.068	0.503
377	Wu and Jiang [57]	C	F	150	0.50	36.7	121.2	3.31	0.23	3.52	15.27	1.52	6.59	242	0.102	0.670
378	Wu and Jiang [57]	C	F	150	0.50	36.7	128.6	3.51	0.23	3.37	14.62	1.54	6.68	242	0.102	0.679
379	Wu and Jiang [57]	C	F	150	0.50	36.7	116.5	3.18	0.23	3.25	14.10	1.70	7.37	242	0.102	0.749
380	Wu and Jiang [57]	C	F	150	0.67	36.7	141.8	3.87	0.23	3.49	15.14	1.62	7.03	242	0.136	0.952

381	Ozbakkaloglu [25]	C	F	152	0.23	59.0	66.9	1.13	0.26	1.00	3.85	1.17	4.51	240	0.033	0.147
382	Ozbakkaloglu [25]	C	F	152	0.47	59.0	83.0	1.41	0.26	1.27	4.89	0.97	3.74	240	0.065	0.243
383	Ozbakkaloglu [25]	C	F	152	0.23	36.4	60.6	1.66	0.23	1.47	6.39	1.30	5.65	240	0.047	0.264
384	Ozbakkaloglu [25]	C	F	302	0.47	36.3	57.0	1.57	0.23	1.52	6.61	1.17	5.09	240	0.047	0.240
385	Ozbakkaloglu [25]	C	F	74	0.12	43.0	69.2	1.61	0.24	1.40	5.83	1.20	5.00	240	0.042	0.212
386	Ozbakkaloglu [25]	C	F	152	0.59	102.5	116.0	1.13	0.30	1.04	3.49	0.81	2.72	240	0.054	0.146
387	Zohrevand and Mirmiran [58]	C-U	M	108	2.04	188.2	254.1	1.35	0.35	0.68	1.96	0.69	1.99	71	0.049	0.098
388	Zohrevand and Mirmiran [58]	C-U	M	108	4.08	188.2	372.2	1.98	0.35	1.05	3.03	0.80	2.31	71	0.098	0.227
389	Kshirsagar et al. [59][a]	G	F	102	1.42	38.0	57.0	1.50	0.23	1.73	7.44	1.74	7.48	20	0.034	0.254
390	Kshirsagar et al. [59][a]	G	F	102	1.42	39.4	63.1	1.60	0.23	1.60	6.82	2.07	8.82	20	0.033	0.291
391	Kshirsagar et al. [59][a]	G	F	102	1.42	39.5	60.4	1.53	0.23	1.79	7.62	1.89	8.05	20	0.033	0.265
392	Aire et al. [31][a]	G	M	150	0.15	42.0	41.0	0.98	0.24	0.73	3.06	0.55	2.31	65	0.007	0.017
393	Aire et al. [31][a]	G	M	150	0.45	42.0	61.0	1.45	0.24	1.74	7.29	1.30	5.45	65	0.022	0.120
394	Aire et al. [31][a]	G	M	150	0.89	42.0	85.0	2.02	0.24	2.50	10.48	1.10	4.61	65	0.044	0.203
395	Micelli et al. [32][a]	G	M	102	0.35	32.0	52.0	1.63	0.22	1.25	5.61	1.25	5.61	72	0.034	0.193
396	Pessiki et al.[60][a]	G	M	152	1.00	26.2	38.4	1.47	0.21	1.30	6.13	1.15	5.42	22	0.023	0.125
397	Pessiki et al.[60][a]	G	M	152	2.00	26.2	52.5	2.00	0.21	1.82	8.59	1.24	5.85	22	0.046	0.269
398	Toutanji [8]	G	F	76	0.24	30.9	60.8	1.97	0.22	1.53	6.92	1.63	7.38	73	0.033	0.242
399	Lam and Teng [36]	G	F	152	1.27	38.5	51.9	1.35	0.23	1.32	5.63	1.44	6.18	22	0.023	0.141
400	Lam and Teng [36]	G	F	152	1.27	38.5	58.3	1.51	0.23	1.46	6.25	1.89	8.08	22	0.023	0.184
401	Lam and Teng [36]	G	F	152	2.54	38.5	75.7	1.97	0.23	2.46	10.53	1.76	7.55	22	0.045	0.343
402	Lam and Teng [36]	G	F	152	2.54	38.5	77.3	2.01	0.23	2.19	9.37	1.67	7.17	22	0.045	0.326
403	Silva and Rodrigues [61]	G	F	150	2.54	27.4	91.6	3.34	0.21	2.61	12.17	1.99	9.26	21	0.056	0.523
404	Silva and Rodrigues [61]	G	F	150	2.54	27.4	89.4	3.26	0.21	2.72	12.69	1.89	8.82	21	0.056	0.498
405	Berthet et al. [37]	G	M	160	0.33	25.0	42.8	1.71	0.21	1.70	8.10	1.66	7.90	74	0.026	0.202
406	Berthet et al. [37]	G	M	160	0.33	25.0	42.3	1.69	0.21	1.69	8.05	1.64	7.84	74	0.026	0.201
407	Berthet et al. [37]	G	M	160	0.33	25.0	43.1	1.72	0.21	1.71	8.17	1.67	7.98	74	0.026	0.204
408	Berthet et al. [37]	G	M	160	0.22	40.1	44.8	1.12	0.24	0.53	2.23	1.37	5.81	74	0.012	0.069
409	Berthet et al. [37]	G	M	160	0.22	40.1	46.3	1.15	0.24	0.47	1.98	1.25	5.28	74	0.012	0.063
410	Berthet et al. [37]	G	M	160	0.22	40.1	49.8	1.24	0.24	0.50	2.10	1.08	4.56	74	0.012	0.055
411	Berthet et al. [37]	G	M	160	0.33	40.1	50.8	1.27	0.24	0.63	2.68	0.90	3.82	74	0.018	0.069
412	Berthet et al. [37]	G	M	160	0.33	40.1	50.8	1.27	0.24	0.58	2.47	1.28	5.43	74	0.018	0.098
413	Berthet et al. [37]	G	M	160	0.33	40.1	51.8	1.29	0.24	0.64	2.69	1.20	5.08	74	0.018	0.091
414	Berthet et al. [37]	G	M	160	0.55	40.1	66.7	1.66	0.24	1.05	4.45	1.55	6.56	74	0.030	0.196
415	Berthet et al. [37]	G	M	160	0.55	40.1	68.2	1.70	0.24	1.24	5.26	1.82	7.71	74	0.030	0.231

416	Berthet et al. [37]	G	M	160	0.55	40.1	67.7	1.69	0.24	1.17	4.95	1.58	6.71	74	0.030	0.201
417	Berthet et al. [37]	G	M	160	0.50	52.0	64.7	1.24	0.25	0.53	2.10	1.19	4.73	74	0.022	0.105
418	Berthet et al. [37]	G	M	160	0.50	52.0	75.1	1.44	0.25	1.13	4.50	1.27	5.03	74	0.022	0.111
419	Berthet et al. [37]	G	M	160	0.50	52.0	76.1	1.46	0.25	1.17	4.65	1.27	5.06	74	0.022	0.112
420	Youseff [43][b]	G	N	406	1.68	29.4	44.1	1.50	0.22	0.73	3.34	0.83	3.82	18	0.011	0.043
421	Youseff [43][b]	G	N	406	3.35	29.4	49.5	1.68	0.22	0.93	4.25	1.53	7.02	18	0.023	0.159
422	Youseff [43][b]	G	N	406	4.47	29.4	55.2	1.88	0.22	1.18	5.40	0.60	2.77	18	0.030	0.083
423	Youseff [43][b]	G	N	406	7.26	29.4	73.1	2.48	0.22	1.45	6.66	1.40	6.40	18	0.049	0.314
424	Youseff [43][b]	G	N	153	1.68	44.1	65.5	1.48	0.24	1.32	5.45	1.71	7.09	18	0.022	0.157
425	Youseff [43][b]	G	N	153	2.24	44.1	80.5	1.82	0.24	1.51	6.26	1.87	7.74	18	0.030	0.229
426	Youseff [43][b]	G	N	153	3.35	44.1	91.8	2.08	0.24	2.01	8.34	2.09	8.64	18	0.044	0.382
427	Carey [62][b]	G	N	153	0.51	31.8	37.2	1.17	0.22	0.65	2.92	1.21	5.45	61	0.028	0.154
428	Carey [62][b, d]	G	N	153	1.53	31.8	53.2	1.67	0.22	0.95	4.27	1.43	6.44	61	0.085	0.546
429	Kharel [63][b]	G	N	153	0.17	32.1	36.3	1.13	0.22	0.26	1.17	0.45	2.01	61	0.009	0.019
430	Kharel [63][b]	G	N	153	0.34	32.1	35.6	1.11	0.22	0.35	1.57	0.65	2.91	61	0.019	0.054
431	Kharel [63][b]	G	N	153	0.51	32.1	34.3	1.07	0.22	0.45	2.02	0.74	3.32	61	0.028	0.093
432	Kharel [63][b]	G	N	153	1.02	32.1	38.2	1.19	0.22	0.57	2.56	0.79	3.56	61	0.056	0.200
433	Kharel [63][b]	G	N	153	1.53	32.1	46.7	1.45	0.22	0.68	3.05	0.94	4.22	61	0.084	0.356
434	Kharel [63][b, d]	G	N	153	2.04	32.1	50.2	1.56	0.22	0.82	3.68	0.91	4.07	61	0.112	0.457
435	Kharel [63][b, d]	G	N	153	2.55	32.1	60.0	1.87	0.22	0.87	3.90	0.89	3.99	61	0.140	0.560
436	Kharel [63][b]	G	N	153	0.40	32.1	44.4	1.38	0.22	1.18	5.29	1.50	6.73	101	0.037	0.248
437	Kharel [63][b]	G	N	153	0.80	32.1	62.1	1.93	0.22	1.71	7.67	1.28	5.74	101	0.074	0.423
438	Bullo [45][c]	G	N	150	0.46	32.5	72.4	2.23	0.22	3.73	16.67	2.15	9.60	65	0.027	0.263
439	Bullo [45][c]	G	N	150	0.46	32.5	73.6	2.26	0.22	3.93	17.56	2.17	9.72	65	0.027	0.266
440	Bullo [45][c]	G	N	150	0.46	32.5	75.8	2.33	0.22	2.85	12.74	2.04	9.13	65	0.027	0.250
441	Bullo [45][c]	G	N	150	1.15	32.5	118.8	3.65	0.22	4.28	19.12	1.97	8.78	65	0.069	0.602
442	Bullo [45][c]	G	N	150	1.15	32.5	130.2	4.00	0.22	4.04	18.05	1.91	8.55	65	0.069	0.586
443	Bullo [45][c]	G	N	150	1.15	32.5	135.8	4.17	0.22	4.84	21.63	1.81	8.08	65	0.069	0.554
444	Cui and Sheikh [50]	G	F	152	1.25	47.7	59.1	1.24	0.25	1.35	5.48	2.02	8.20	21	0.018	0.150
445	Cui and Sheikh [50]	G	F	152	1.25	47.7	59.8	1.25	0.25	1.15	4.67	2.14	8.70	21	0.018	0.159
446	Cui and Sheikh [50]	G	F	152	2.50	47.7	88.9	1.86	0.25	2.21	8.97	2.03	8.25	21	0.036	0.301
447	Cui and Sheikh [50]	G	F	152	2.50	47.7	88.0	1.84	0.25	2.21	8.97	2.11	8.58	21	0.036	0.313
448	Cui and Sheikh [50]	G	F	152	3.75	47.7	113.2	2.37	0.25	2.85	11.57	2.11	8.58	21	0.055	0.469
449	Cui and Sheikh [50]	G	F	152	3.75	47.7	112.5	2.36	0.25	2.80	11.37	2.11	8.57	21	0.055	0.469
450	Cui and Sheikh [50]	G	F	152	1.25	47.7	63.4	1.33	0.25	1.51	6.13	2.18	8.85	21	0.018	0.161

451	Cui and Sheikh [50]	G	F	152	1.25	47.7	62.4	1.31	0.25	1.35	5.48	2.12	8.59	21	0.018	0.157
452	Cui and Sheikh [50]	G	F	152	2.50	47.7	89.7	1.88	0.25	2.14	8.69	2.07	8.42	21	0.036	0.307
453	Cui and Sheikh [50]	G	F	152	2.50	47.7	88.3	1.85	0.25	2.05	8.33	2.05	8.32	21	0.036	0.303
454	Cui and Sheikh [50]	G	F	152	3.75	47.7	108.0	2.26	0.25	2.62	10.64	1.89	7.69	21	0.055	0.420
455	Cui and Sheikh [50]	G	F	152	1.25	79.9	66.7	0.83	0.28	0.76	2.71	2.02	7.20	21	0.012	0.089
456	Cui and Sheikh [50]	G	F	152	1.25	79.9	74.7	0.93	0.28	0.88	3.13	2.42	8.63	21	0.012	0.107
457	Cui and Sheikh [50]	G	F	152	2.50	79.9	92.5	1.16	0.28	0.86	3.08	1.39	4.96	21	0.025	0.123
458	Cui and Sheikh [50]	G	F	152	2.50	79.9	94.1	1.18	0.28	0.78	2.77	1.69	6.05	21	0.025	0.150
459	Cui and Sheikh [50]	G	F	152	3.75	79.9	120.8	1.51	0.28	1.26	4.48	2.01	7.17	21	0.037	0.266
460	Cui and Sheikh [50]	G	F	152	3.75	79.9	126.1	1.58	0.28	1.18	4.22	1.92	6.84	21	0.037	0.254
461	Cui and Sheikh [50]	G	F	152	2.50	79.9	106.3	1.33	0.28	0.67	2.37	1.19	4.26	21	0.025	0.105
462	Cui and Sheikh [50] [e]	G	F	152	2.50	79.9	100.3	1.26	0.28	0.46	1.64	1.08	3.86	21	0.025	0.095
463	Cui and Sheikh [50] [e]	G	F	152	5.00	79.9	174.6	2.19	0.28	0.95	3.39	1.40	4.99	21	0.050	0.247
464	Cui and Sheikh [50]	G	F	152	5.00	79.9	172.9	2.16	0.28	1.28	4.58	1.54	5.49	21	0.050	0.272
465	Demers and Neale [46][c]	G	M	152	1.05	32.2	48.3	1.50	0.22	2.04	9.14	1.65	7.39	11	0.010	0.074
466	Demers and Neale [46][c]	G	M	152	1.05	32.2	48.3	1.50	0.22	1.97	8.83	1.83	8.18	11	0.010	0.082
467	Jiang and Teng [47]	G	F	152	0.17	33.1	42.4	1.28	0.22	1.30	5.78	2.08	9.25	80	0.012	0.113
468	Jiang and Teng [47]	G	F	152	0.17	33.1	41.6	1.26	0.22	1.27	5.65	1.76	7.82	80	0.012	0.095
469	Jiang and Teng [47]	G	F	152	0.17	45.9	48.4	1.05	0.24	0.81	3.32	1.52	6.24	80	0.010	0.059
470	Jiang and Teng [47]	G	F	152	0.17	45.9	46.0	1.00	0.24	1.06	4.35	1.92	7.85	80	0.010	0.075
471	Jiang and Teng [47]	G	F	152	0.34	45.9	52.8	1.15	0.24	1.20	4.92	1.64	6.72	80	0.019	0.128
472	Jiang and Teng [47]	G	F	152	0.34	45.9	55.2	1.20	0.24	1.25	5.13	1.80	7.38	80	0.019	0.140
473	Jiang and Teng [47]	G	F	152	0.51	45.9	64.6	1.41	0.24	1.55	6.36	1.59	6.54	80	0.029	0.187
474	Jiang and Teng [47]	G	F	152	0.51	45.9	65.9	1.44	0.24	1.90	7.79	1.94	7.95	80	0.029	0.227
475	Mastrapa [64] [e]	G	S	153	0.61	29.8	33.7	1.13	0.22	0.25	1.14	2.06	9.41	19	0.011	0.106
476	Mastrapa [64]	G	S	153	1.84	31.2	67.5	2.16	0.22	2.95	13.32	2.23	10.08	19	0.033	0.330
477	Mastrapa [64]	G	S	153	1.84	31.2	64.7	2.07	0.22	3.15	14.22	1.97	8.90	19	0.033	0.292
478	Mastrapa [64]	G	S	153	3.07	31.2	91.0	2.92	0.22	3.80	17.16	1.80	8.12	19	0.055	0.444
479	Mastrapa [64]	G	S	153	3.07	31.2	96.9	3.11	0.22	6.20	28.00	1.77	7.99	19	0.055	0.437
480	Teng et al. [65]	G-T	F	152	0.17	39.6	41.5	1.05	0.24	0.83	3.51	1.87	7.95	80	0.011	0.085
481	Teng et al. [65]	G-T	F	152	0.17	39.6	40.8	1.03	0.24	0.94	4.01	1.61	6.85	80	0.011	0.073
482	Teng et al. [65]	G-T	F	152	0.34	39.6	54.6	1.38	0.24	2.13	9.06	2.04	8.68	80	0.021	0.185
483	Teng et al. [65]	G-T	F	152	0.34	39.6	56.3	1.42	0.24	1.83	7.76	2.06	8.77	80	0.021	0.187
484	Teng et al. [65]	G-T	F	152	0.51	39.6	65.7	1.66	0.24	2.56	10.88	1.96	8.32	80	0.032	0.265
485	Teng et al. [65]	G-T	F	152	0.51	39.6	60.9	1.54	0.24	1.79	7.62	1.67	7.09	80	0.032	0.226

486	Almusallam [66][c]	G	N	150	1.30	47.7	56.7	1.19	0.25	1.50	6.09	0.84	3.41	27	0.024	0.082
487	Almusallam [66][c]	G	N	150	3.90	47.7	100.1	2.10	0.25	2.72	11.05	0.80	3.25	27	0.072	0.235
488	Almusallam [66][c]	G	N	150	1.30	50.8	55.5	1.09	0.25	1.21	4.84	1.00	4.00	27	0.023	0.092
489	Almusallam [66][c]	G	N	150	3.90	50.8	90.8	1.79	0.25	1.88	7.52	0.80	3.20	27	0.069	0.221
490	Almusallam [66][c]	G	N	150	1.30	60.0	62.4	1.04	0.26	0.50	1.92	0.50	1.92	27	0.020	0.039
491	Almusallam [66][c]	G	N	150	3.90	60.0	99.6	1.66	0.26	1.67	6.40	0.70	2.68	27	0.061	0.164
492	Almusallam [66][c]	G	N	150	1.30	80.8	88.9	1.10	0.28	0.36	1.28	0.24	0.85	27	0.016	0.014
493	Almusallam [66][c]	G	N	150	3.90	80.8	100.9	1.25	0.28	0.63	2.24	0.86	3.06	27	0.049	0.149
494	Almusallam [66][c]	G	N	150	1.30	90.3	97.0	1.07	0.29	0.32	1.11	0.26	0.90	27	0.015	0.013
495	Almusallam [66][c]	G	N	150	3.90	90.3	110.0	1.22	0.29	0.93	3.22	0.82	2.84	27	0.045	0.127
496	Almusallam [66][c]	G	N	150	1.30	107.8	116.0	1.08	0.30	0.29	0.96	0.30	0.99	27	0.013	0.013
497	Almusallam [66][c, e]	G	N	150	3.90	107.8	125.2	1.16	0.30	0.26	0.86	0.30	0.99	27	0.039	0.039
498	Micelli and Modarelli [56]	G	F	150	0.23	28.4	53.3	1.88	0.22	1.90	8.79	4.98	23.03	85	0.020	0.458
499	Zohrevand and Mirmiran [58]	G-U	M	108	2.04	188.2	188.4	1.00	0.35	0.40	1.15	0.10	0.29	26	0.018	0.005
500	Zohrevand and Mirmiran [58]	G-U	M	108	3.06	188.2	226.6	1.20	0.35	0.86	2.48	1.20	3.46	26	0.027	0.094
501	Zohrevand and Mirmiran [58]	G-U	M	108	4.08	188.2	273.5	1.45	0.35	1.06	3.05	1.35	3.89	26	0.036	0.141
502	Zohrevand and Mirmiran [58]	G-U	M	108	5.10	188.2	298.9	1.59	0.35	1.15	3.31	1.40	4.03	26	0.045	0.183
503	Ozbakkaloglu [25]	A	F	100	0.40	83.6	113.6	1.36	0.28	1.63	5.75	1.84	6.49	116	0.031	0.204
504	Ozbakkaloglu [25]	A	F	100	0.60	85.9	154.1	1.79	0.29	2.18	7.64	1.85	6.49	116	0.046	0.300
505	Ozbakkaloglu [25]	A	F	152	0.60	77.9	108.3	1.39	0.28	1.85	6.65	1.83	6.57	116	0.033	0.215
506	Ozbakkaloglu [25]	A	F	100	0.20	35.5	66.3	1.87	0.23	1.90	8.31	2.18	9.53	116	0.030	0.285
507	Ozbakkaloglu [25]	A	F	100	0.60	110.1	154.1	1.40	0.30	1.89	6.23	1.55	5.11	116	0.038	0.196
508	Ozbakkaloglu [25]	A	F	100	0.80	110.1	187.4	1.70	0.30	2.34	7.71	1.52	5.01	116	0.051	0.256
509	Ozbakkaloglu [25]	A	F	152	0.80	102.2	122.3	1.20	0.30	1.45	4.87	1.18	3.96	116	0.036	0.141
510	Ozbakkaloglu [25]	A	F	152	1.20	104.5	173.8	1.66	0.30	2.12	7.08	1.58	5.27	116	0.053	0.277
511	Ozbakkaloglu [25]	A	F	152	0.60	49.4	106.3	2.15	0.25	3.39	13.65	2.32	9.34	116	0.046	0.430
512	Watanable et al. [22][a]	A	F	100	0.15	30.2	39.0	1.29	0.22	1.58	7.19	2.36	10.74	91	0.020	0.213
513	Watanable et al. [22][a]	A	F	100	0.29	30.2	68.5	2.27	0.22	4.75	21.62	3.09	14.07	91	0.038	0.540
514	Watanable et al. [22][a]	A	F	100	0.43	30.2	92.1	3.05	0.22	5.55	25.27	2.65	12.06	91	0.057	0.687
515	Rochette and Labossiere [26][a]	A	F	150	1.27	43.0	47.3	1.10	0.24	1.11	4.63	1.53	6.38	14	0.013	0.082
516	Rochette and Labossiere [26][a]	A	F	150	2.56	43.0	58.9	1.37	0.24	1.47	6.13	1.39	5.79	14	0.026	0.150
517	Rochette and Labossiere [26][a]	A	F	150	3.86	43.0	71.0	1.65	0.24	1.69	7.04	1.33	5.54	14	0.039	0.216
518	Rochette and Labossiere [26][a]	A	F	150	5.21	43.0	74.4	1.73	0.24	1.74	7.25	1.18	4.92	14	0.053	0.259

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[a] Sourc of data point is Lam and Teng [9]

[b] Sourc of data point is Carey and Harries [14]

[c] Sourc of data point is Realfonzo and Napoli [15]

[d] this data point was not included in the evaluation of strength models

[e] this data point was not included in the evaluation of strain models

HC: high modulus carbon, C: carbon, G: glass, A: aramid

R: internal axial and transverse steel rebars, T: internal hollow steel tube (76.1 mm outer diameter and 3.2 mm thickness), H: internal hole (50 mm diameter), U: ultra-high performance concrete

F: flat coupon test, M: manufacturer data sheet, S: split disc coupon test, N: not available

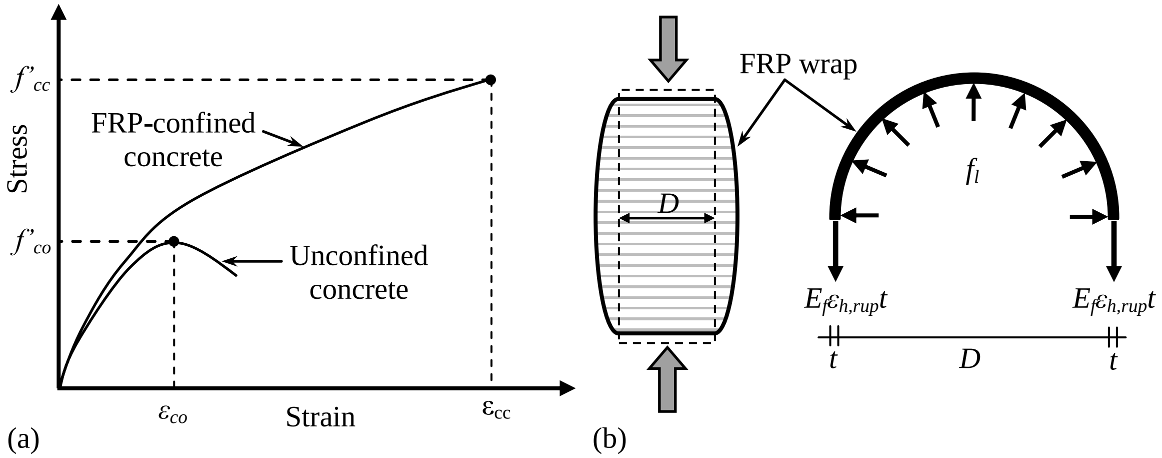

Figure 1. Mechanism of confinement in FRP-confined concrete

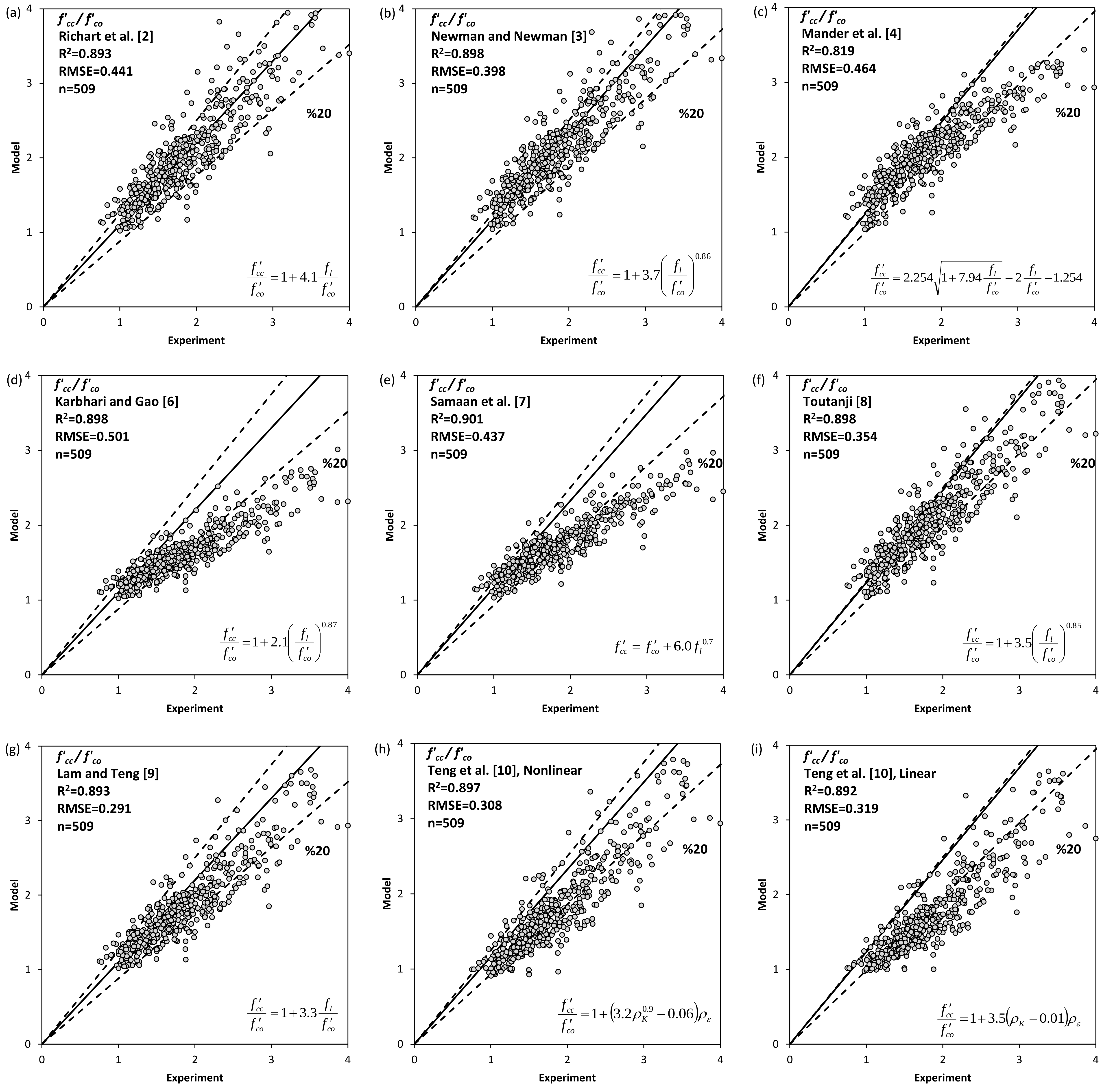

Figure 2. Performance of existing strength models

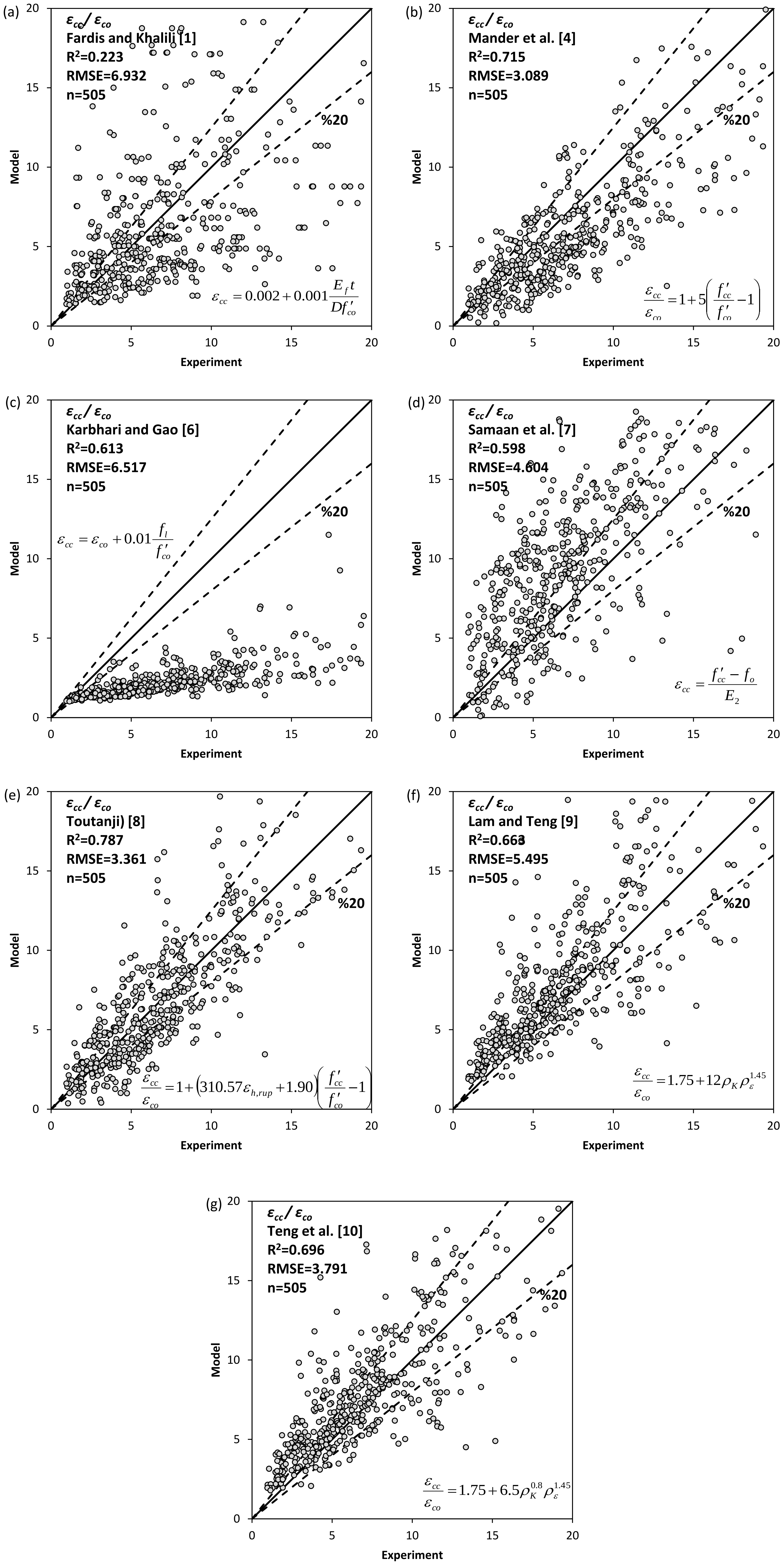

Figure 3. Performance of existing strain models

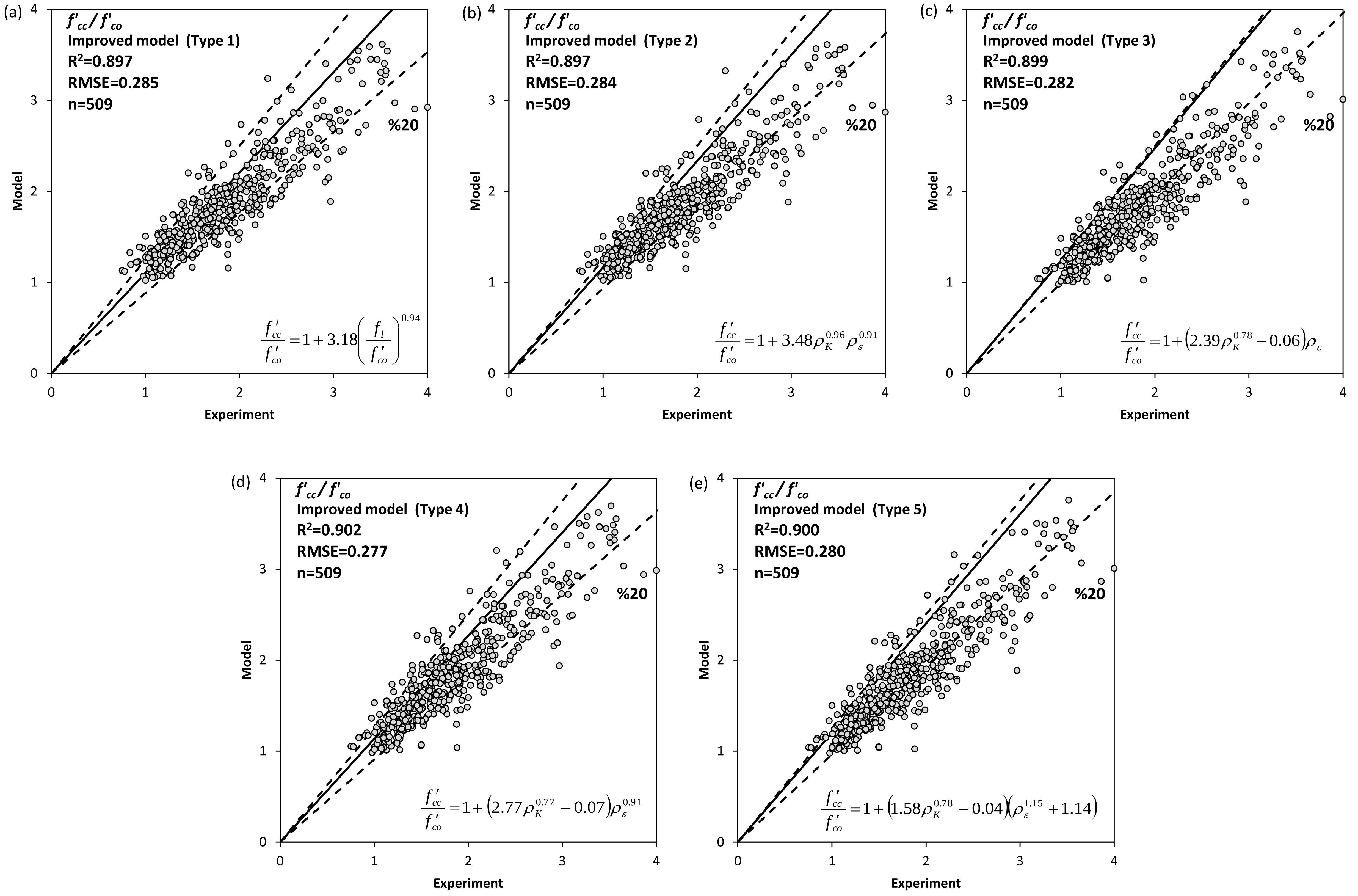

Figure 4. Performance of improved strength models

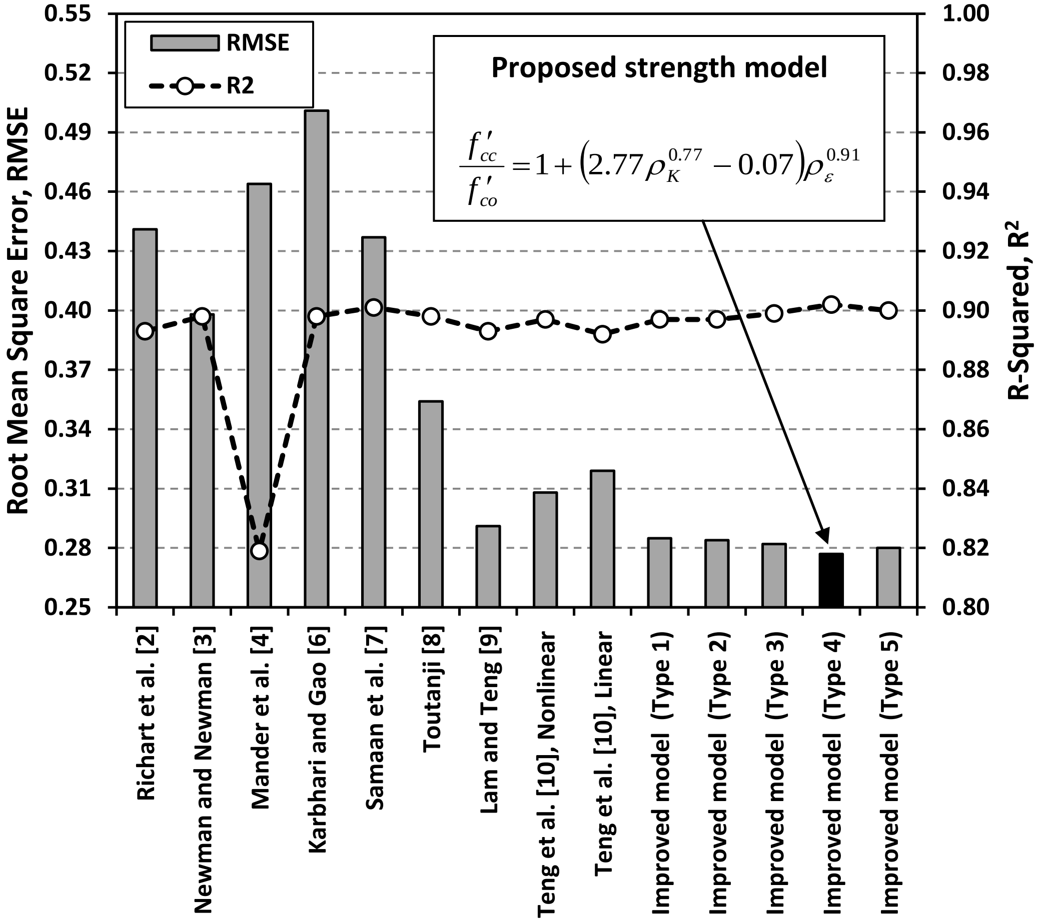

Figure 5. Performance of existing, improved, and proposed strength models based on 509 data points

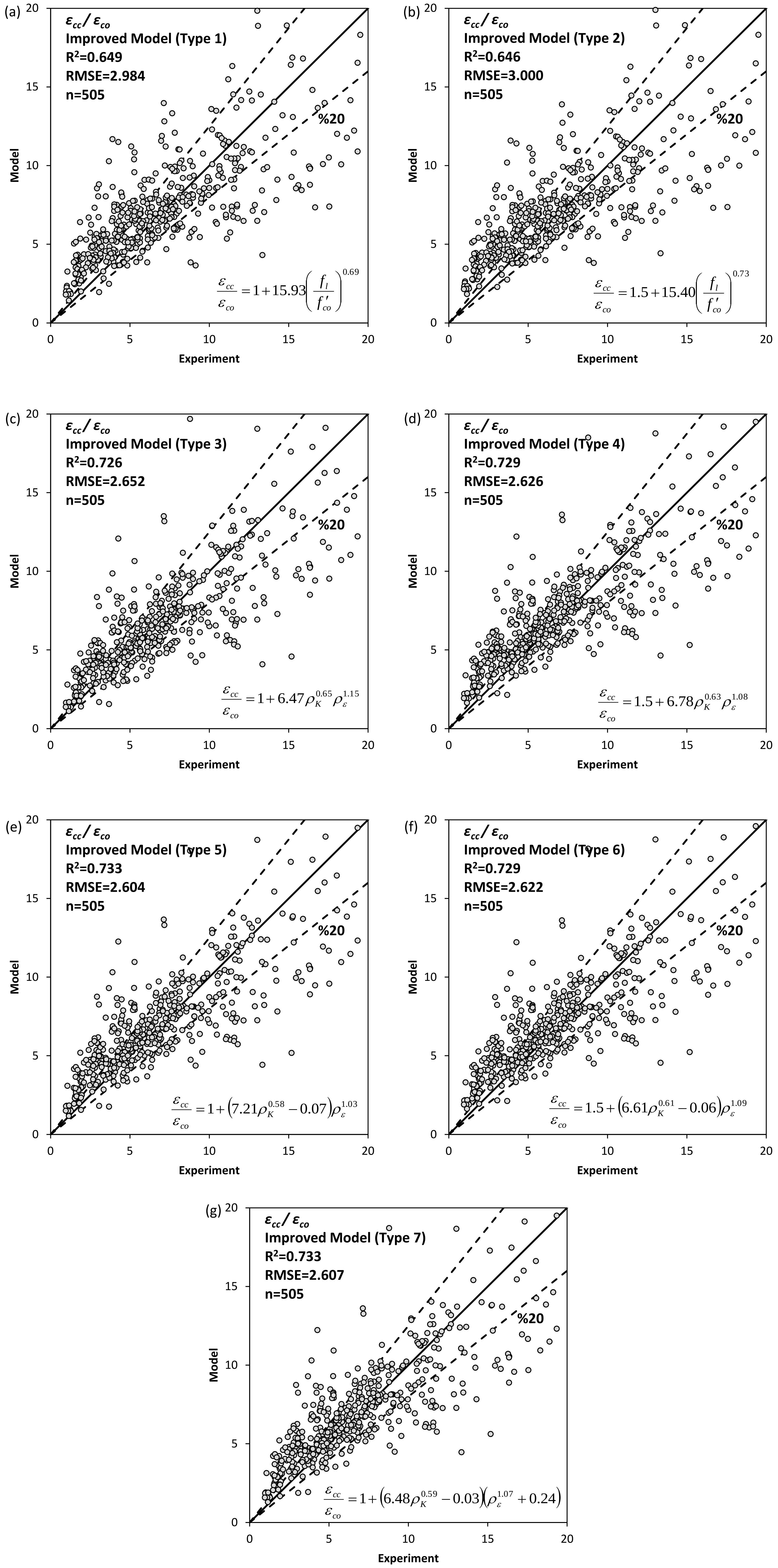

Figure 6. Performance of Improved strain models

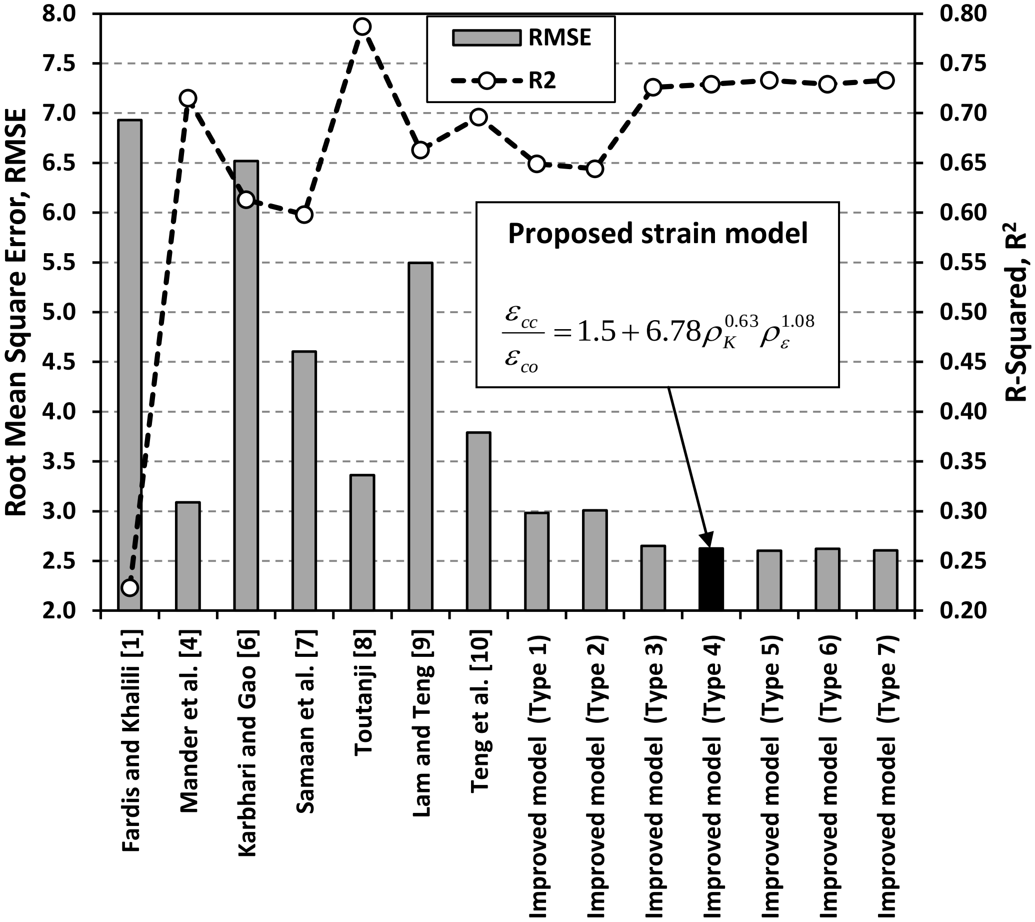

Figure 7. Performance of existing, improved, and proposed strain models based on 505 data points

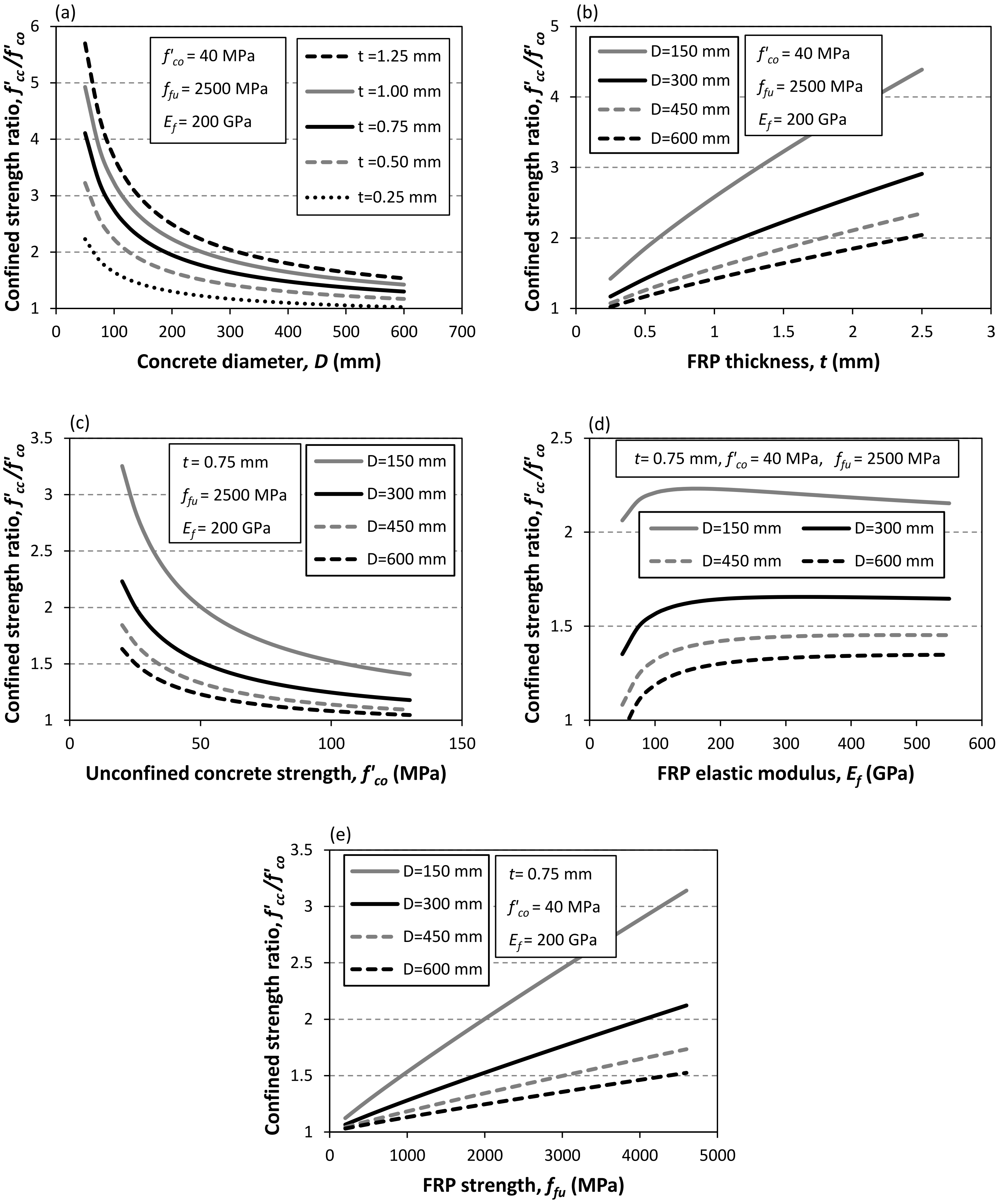

Figure 8. Parametric study of cylindrical FRP-confined concrete using proposed strength model

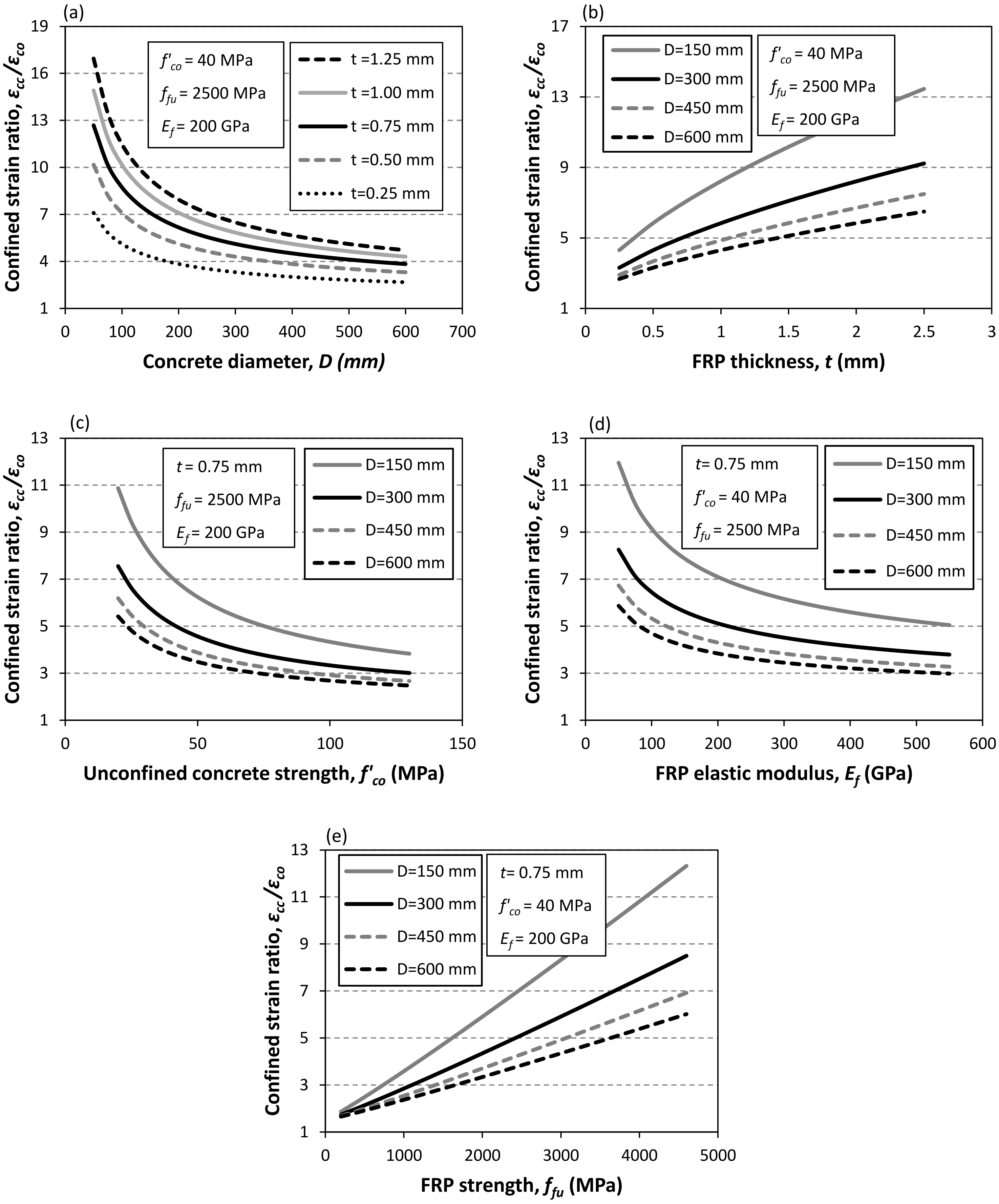

Figure 9. Parametric study of cylindrical FRP-confined concrete using proposed strain model