Compressive Strength Evaluation of Concrete Confined With Spiral Stirrups by Using Adaptive Neuro-fuzzy Inference System (ANFIS)

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Research Article

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Abstract: The compressive strength of concrete confined with spiral stirrups was an important parameter to evaluate the load-bearing capacity of concrete columns. The confinement provided by spiral stirrups let concrete under the triaxial compression state and improved the compressive strength of concrete. However, the relationships between concrete and stirrups were complex and the existing prediction models for evaluating the compressive strength of confined concrete were various. In this paper, an adaptive neural-fazzy inferenxe system (ANFIS) model was developed to evaluate the compressive strength of concrete confined with stirrups. A set of 231 experimental results of concrete confined with spiral stirrups were collected from the previous studies to establish a reliable database. The investigated parameters included the aspect ratio of specimens, the diameter, spacing, yield strength, and volumetric ratio of stirrups, the ratio of longitudinal reinforcement, and the compressive strength of concrete. The results showed that the ANFIS model predicted the compressive strength of confined concrete accurately. By comparing with existing models, the proposed ANFIS model had high applicable and reliability. The effects of the investigated parameters on the compressive strength of concrete were analyzed based on the proposed ANFIS model.

Keywords: Adaptive neural-fuzzy inference system (ANFIS); compressive strength; confined concrete; spiral stirrups; prediction model

1. Introduction

The compressive strength of concrete was a crucial parameter to evaluate the load-bearing capacity of concrete columns. The compressive strength of concrete would be enhanced when concrete was confined with stirrups, which let concrete under triaxial compression [1]. It was important to evaluate the compressive strength of confined concrete. The compressive strength of confined concrete was close related to the mechanical properties of stirrups [2]. However, the relationships between concrete and stirrups were complex, which can be attributed to the tensile strength of stirrups may not reach the yield strength at the compressive strength of confined concrete [3]. It was not suitable for evaluating the compressive strength of confined concrete by using the tensile strength; on the other hand, the existing models models for evaluating the compressive strength of confined concrete were proposed by the limited experimental data sets, which should be reevaluated when the new test data were introduced. Thus, it was necessary to establish a reliable prediction model to estimate the compressive strength of concrete confined with spiral stirrups.

The compression behavior of concrete confined with spiral stirrups has been studied over one century and many typical prediction models for evaluating the compressive strength of confined concrete were proposed. Richard et al. explored the compression behavior of confined concrete, and found that the compressive strength of confined concrete was improved by lateral confinement of stirrups [4]. Besides, they firstly proposed the prediction models for evaluating the compressive strength of confined concrete [5]. Mander et al. indicated that longitudinal reinforcement and spiral stirrups both had obvious effects on the compressive strength of concrete based on the experimental results and theoretical analysis [6] and the analytical model for predicting the compressive strength of confined concrete by considering the effects of longitudinal reinforcement and stirrups based on the "Mohr-Coulomb criteria"[7]. Cusson proposed the concept of "confinement index", which was the ratio between the lateral confining stress and compressive stress of unconfined concrete, to evaluate the compressive strength of confined concrete [8]. Legeron proposed a prediction model for evaluating the compressive strength of confined concrete based on the theoretical analysis and a large experimental results [3]. Bing found that the high strength of spiral stirrups can significantly improve the compressive strength of confined concrete [9]. Saatcioglu and Razvi indicated that the lateral confining stress decreased exponentially with the increase of concrete compressive strength [10]. Sharma thought that the load-bearing capacity of confined concrete columns would be decreased with the increase of the compressive strength of concrete, while the volumetric ratio and spacing of stirrups had obvious influence on the compressive behavior of confined concrete [11]. Wang founded that the compressive strength of confined concrete increased with the increased of the yield strength of stirrups, while the volumetric ratio of stirrups also had the same effects [12]. Wei demonstrated that the high strength steel wire can effectively improved the compressive strength of confined concrete [13]. Cao found that the high strength stirrups had insignificant effects on the load-bearing capacity of confined concrete [14]. Deng et al. found that high strength stirrups had superiority in improving the compressive strength of confined concrete compared with normal strength stirrups [15]. Based on the previous studies, the effects of the influential parameters on the compressive strength of confined concrete only considered the yield strength and the volumetric ratio of stirrups, and as well as the compressive strength of concrete. Moreover, the existing prediction models were established based a specific set of experimental results, when new test results were introduced, the applicability and reliability of models should be re-evaluated. Moreover, some existing models with numerous variables and complex computational processes were difficult to utilize in practical civil engineering design.

In recent years, adaptive neural-fuzzy inference system (ANFIS) combined with both learning and reasoning capability of artificial neural network and fuzzy logic has been developed for solving the complex problems [16]. Akbarpour proposed an ANFIS model to predict the punching shear strength of two-way slabs based on 189 experimental results and found that the proposed model can evaluate the punching load with an acceptable error [17]. Khademi [18] and Bilgehan [19] predicted the 28 days compressive strength of recycled aggregate concrete by using ANFIS with 14 different input parameters and indicated that the ANFIS model was suggested to be used in the mix design optimization and be utilized for preliminary mix design of concrete, respectively. Vakhshouri designed ANFIS models to establish the relationships between the compressive strength of self-compacting concrete and mixture proportions and slump flow and indicated the proposed models gave the best prediction of the compressive strength [20]. Based on the previous studies, the ANFIS had high prediction performance and good reliable for predicting the mechanical properties of concrete. Thus, ANFIS was suitable for evaluating the compressive strength of concrete confined with stirrups.

The objective of this paper was to evaluate the compressive strength of concrete confined with spiral stirrups. To achieve this purpose, 231-group experimental results of concrete confined with spiral stirrups were collected from previous studies to establish a reliable database. Based on the database, an ANFIS model was developed to evaluate the compressive strength of confined concrete. Furthermore, the effects of the influential parameters on the compressive strength of confined concrete were analyzed.

2. Database preparation

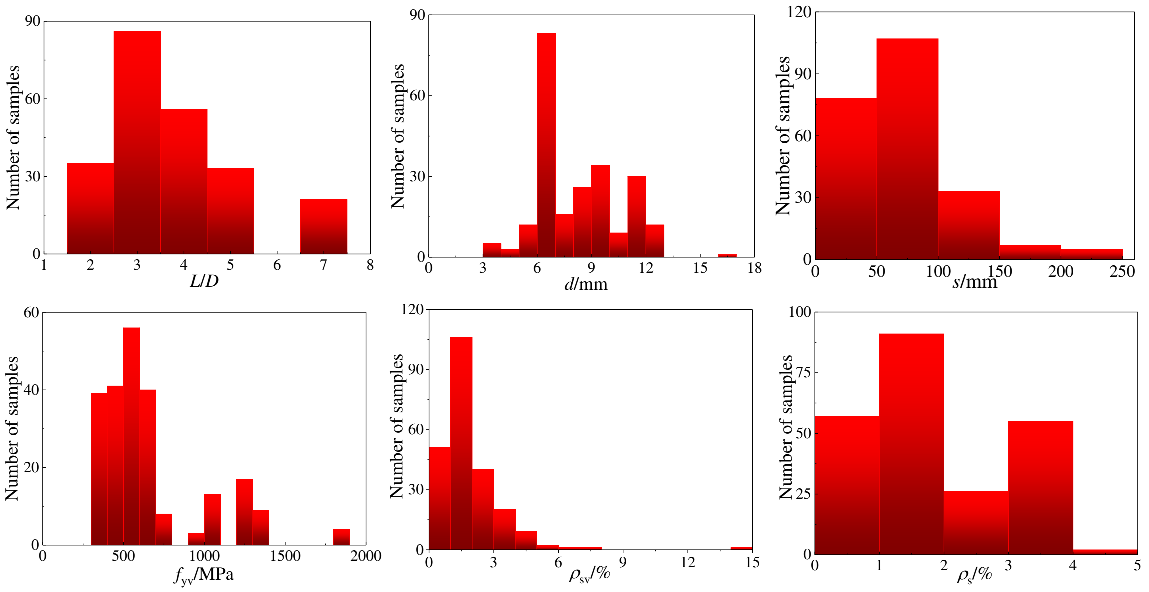
To establish the ANFIS model for evaluating the compressive strength of concrete confined with spiral stirrups, a reliable database consisting of 231-group of experimental results of concrete columns confined with spiral stirrups were gathered from the previous studies was established, listed in Table.5 attached in the appendix [6,22-37]. To ensure the reliable of the database, the collected data should obey the following criteria: (1) all specimens had one layer spiral stirrup; (2) the aspect ratio of all specimens was no more than 8 to avoid the bucking failure; (3) all specimens were tested under monotonically concentric loads.

The compressive strength of concrete confined with spiral stirrups was related to the aspect ratio of specimens, the diameter, spacing, volumetric ratio and yield strength of spiral stirrups, the ratio of longitudinal reinforcement and the compressive strength of concrete. The range of influential parameters was listed in Table.1 and the distribution of the influential parameters were shown in Fig.1.

Table.1 Range of parameters in database

Variables	Minimum	Maximum	Mean	Correlation
L/D	1.67	6.97	3.80	-0.05
d/mm	3	16	7.97	-0.25
s/mm	10	240	66	-0.39
f_{yv}/MPa	307	1803	656	0.19
ρ_{sv}/%	0.28	14.28	1.89	0.55
ρ_s/%	0	4.8	1.66	-0.37
f_c/MPa	21	151	63.29	0.85
f_{cc}/MPa	19.3	259	78.44	1

Where, L/D was the aspect ratio of specimens, L was the height of specimens and D was the diameter of specimens; d was the diameter of stirrups; s was the spacing of stirrups; f_y was the yield strength of specimens; ρ_{sv} was the volumetric ratio of specimens; ρ_s was the ratio of longitudinal reinforcement; f_c was was the compressive strength of concrete; f_{cc} was the compressive strength of confined concrete.



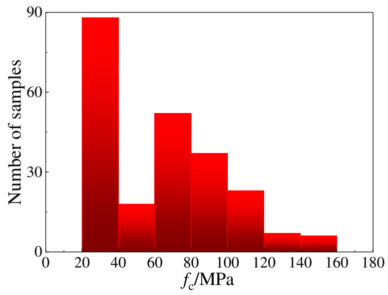


Fig.1 Distribution of influential parameters

3. Adaptive neuro-fuzzy inference system (ANFIS)

3.1 Conception

Adaptive neuro-fuzzy inference system (ANFIS) integrated the advantages of both neural networks and fuzzy logic systems with high self-adaptability and self learning ability to be identified as a universal estimator for responding to complex problems [16]. The ANFIS was a class of adaptive, multi-layer and feed-forward networks which was comprised of input-output varioubs and a fuzzy rule base of the Takagi-Sugeno type [21]. The ANFIS model incorporated the human-like reasoning style of fuzzy inference system through the use of input-output sets and a linguistic model consisting of a set of IF_THEN fuzzy rules, which was expressed as following:

Rule 1: IF x was A_1 and y was B_1, THEN $f_1=p_1x+q_1y+r_1$;

Rule 2: IF x was A_2 and y was B_2, THEN $f_2=p_2x+q_2y+r_2$;

The principle structures of ANFIS model was consisted of fiver layers, including input layer, input membership function layer, rule layer, output membership function layer and output layer [25]. The framework of different layers was different with each other, while the nodes of the same layer performed similarly to each other. The principle structures of ANFIS was shown in Fig.2.

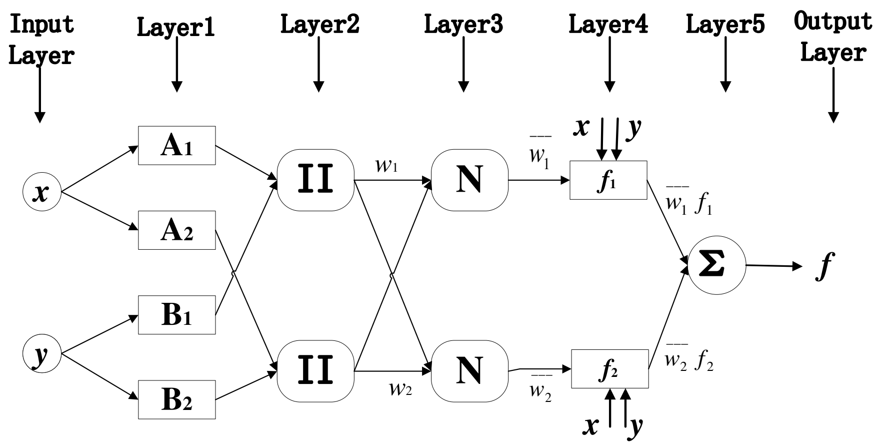


Fig.2 The principle structures of ANFIS

Input layer: the influential parameters determined the number of nodes of the input layer. If the number of input variables was N, the number of input layer nodes was N.

Layer1: the membership function in this layer can fuzzy the input variables. Every node *i* in this layer was a square node with a membership function. The membership function was expressed in Eq.(1).

$$O_i^1 = \mu_{A_i}(x) \tag{1}$$

In which, x was the input variables, A_i was the fuzzy sets; O_i^1 was the subordinative function values of A_i, which represented the degree belonging to A_i; $\mu_{A_i}(x)$ was the membership function.

Layer2: the regular strength release layer. The nodes in this layer were responsibility for multiplying the input signals from the previous layer, meanwhile, the outputs of each node represented the credibility of the rules. The outputs of Layer2 were described in Eq.(2).

$$\omega_i = \mu_{A_i}(x) \times \mu_{B_i}(y) \quad i = 1,2 \tag{2}$$

Where, ω_i was the outputs of the Layer2.

Layer3: the normalization layer of rules. The i^{th} node calculates the ratio of the i^{th} rule firing strength to the sum of all rule firing strength. The outputs of Layer3 were shown in Eq.(3).

$$\overline{\omega_i} = \omega_i \big/ (\omega_1 + \omega_2) \quad i = 1,2 \tag{3}$$

Where, $\overline{\omega_i}$ was the outputs of the Layer3 which also called normalized firing strength.

Layer4: calculating the outputs of fuzzy rules. Each node was an adaptive node and the output was given in Eq.(4).

$$O_i^4 = \overline{\omega_i}\, f_i = \overline{\omega_i}\,(p_i x + q_i y + r_i) \qquad i = 1,2 \tag{4}$$

Where, O_i^4 was the output of Layer4; $\overline{\omega_i}$ was the output of Layer3; $\{p_i, q_i, r_i\}$ were parameter sets of nodes in Layer4.

Layer5: only had one fixed node to calculate the sum of total input signals. The total output of Layer5 was shown in Eq (5).

$$O_i^5 = \sum \overline{\varpi_i} f_i = \sum \overline{\omega_i}\, f_i / \sum \omega_i \qquad i = 1,2 \tag{5}$$

The O_i^5 also can be described as a linear combination of parameter sets of nodes in Layer4.

$$\begin{aligned} O_i^5 &= \overline{\omega_i}\, f_1 + \overline{\omega_i}\, f_2 \\ &= (\overline{\omega_1}\, x) p_1 + (\overline{\omega_1}\, y) q_1 + (\overline{\omega_1}) r_1 + (\overline{\omega_2}\, x) p_2 + (\overline{\omega_2}\, y) q_2 + (\overline{\omega_2}) r_2 \end{aligned} \tag{6}$$

Output layer: the target values were obtained in this layer.

3.2 ANFIS model establishment

In this section, the ANFIS model for evaluating the compressive strength of concrete confined with spiral stirrups was established. The proposed ANFIS model was consisted of seven input parameters including the aspect ratio of specimens, the diameter, spacing, yield strength and volumetric ratio of stirrups, the ratio of longitudinal reinforcement and the compressive strength of concrete and one output variable (the compressive strength of confined concrete). The four membership functions including the triangular, trapezoidal, Gaussian and Π-shape were selected to construct the proposed ANFIS model, named as ANFISI, ANFISII, ANFISIII, ANFISIV, to obtain the suitable membership function, while the membership function in output layer was constant. The ANFIS mode was trained by 185-group data sets and tested by 46-group data sets, which were selected randomly. Up to 100 epochs were specified for the training process to obtain the minimum error tolerance. Furthermore, hybrid learning procedure which combined back-propagation gradient descent and least squares method for identification of premise and consequent parameters was adopted to establish the ANFIS model.

The performance of ANFIS model was examined by RMSE and R2 which were listed in Table.2. In Table.2, all ANFIS models had acceptable prediction performance. Among those models, ANFISIII constructed with Gaussian member function exhibited the best prediction performance, which the *RMSE* were 0.9986 and 0.9026 and the R^2 were 0.9986 and 0.9026 for training and testing phases. Thus, the ANFIS model constructed with Gaussian membership function was determined and the structures of the proposed ANFIS model was shown in Fig.3.

Table.2 The training and testing process of ANFIS model

Name	Training process		Testing process	
	RMSE	R^2	*RMSE*	R^2
ANFISI	2.28	0.9964	31.26	0.7122
ANFISII	4.84	0.9840	43.58	0.6274
ANFISIII	1.50	0.9986	3.87	0.9026
ANFISIV	6.04	0.9562	54.38	0.5764

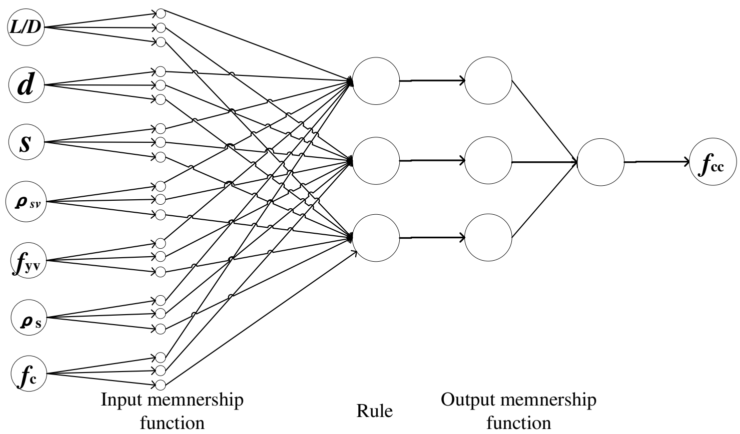


Fig.3 Structures of proposed ANFIS model

3.3 Prediction performance validation

Fig.4 presented the comparison between the predicted results of the proposed ANFIS model and experimental results. In Fig.4, the prediction results from the proposed ANFIS model were well matched the experimental results in training and testing, which meant that the proposed models had good reliable and high performance for evaluating the compressive strength of concrete confined with stirrups.

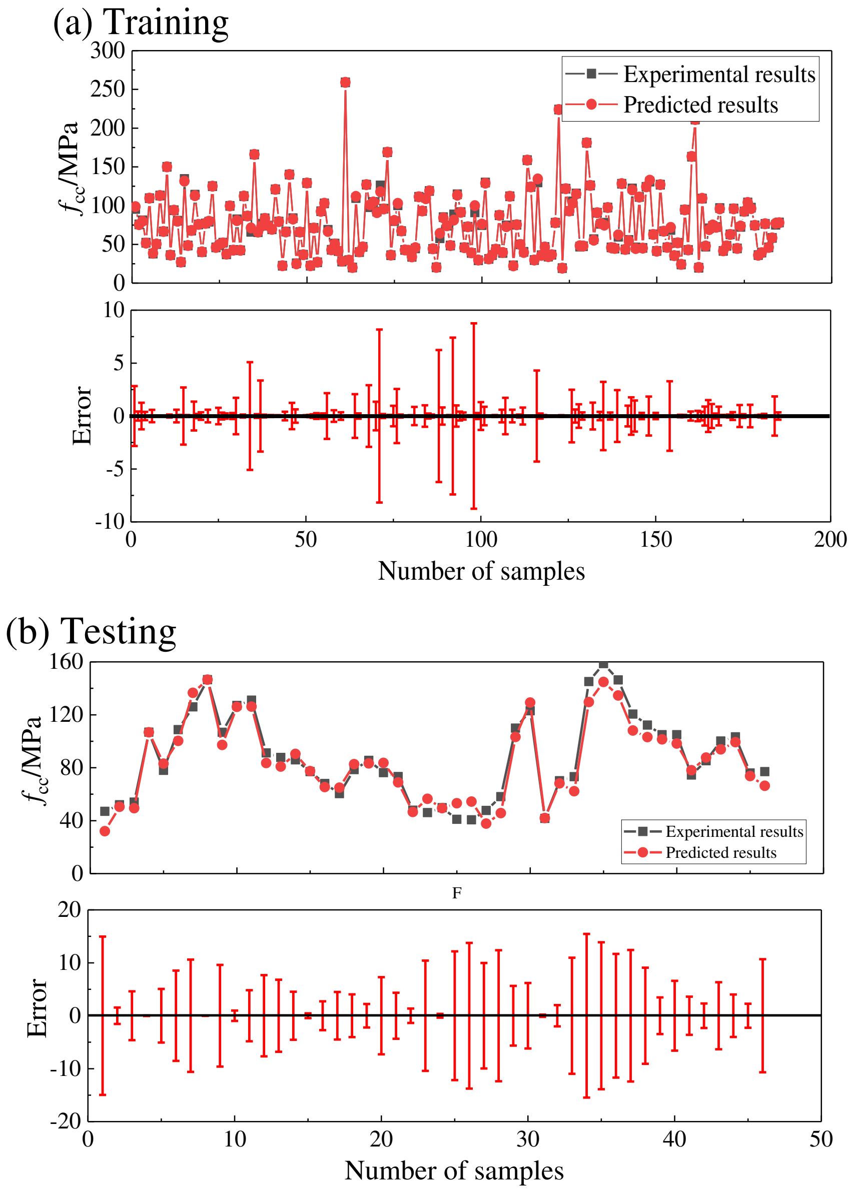


Fig.4 Comparison between predicted results and experimental results

4. Results and discussion

4.1 Results assessment criteria

A successfully trained ANFIS model should give an accurate output prediction, not only for training process but also for new testing data. In this study, four assessment indicators were applied to evaluate the prediction performance of the proposed ANFIS model, which were the root mean square error ($RMSE$), coefficient of determination (R^2), integral absolute error (IAE) and $\alpha 20-\text{index}$ [44], which were expressed in Eqs.(6)-(9).

$$RMSE=\sqrt{\frac{1}{n}\sum_{k=1}^{n}(t_k-o_k)^2} \tag{6}$$

$$R^2=1-\left[\sum_{i=1}^{n}(t_i-o_i)^2 \Big/ \sum_{i=1}^{n}o^2\right] \tag{7}$$

$$IAE=((\sum_{k=1}^{n}(o_k-t_k)^2)^{1/2})/(\sum_{k=1}^{n}o_k)\times 100\% \tag{8}$$

$$\alpha 20-\text{index} = 1-\frac{n20}{n} \tag{9}$$

Where n was the total number of samples; t_k was the experimental result of k^{th} data; 0_k was the output value of k^{th} data; $n20$ was the number of samples which the values of the $f_{\text{cc,predicted}} / f_{\text{cc,experiment}}$ were in the range of 0.8-1.2.

The value of R^2 was applied to evaluate the variation between predicted results and experimental results. The value of *RMSE* and *IAE* were applied to evaluate the errors between predicted results and experimental results. The value of $\alpha 20-\text{index}$ was applied to evaluate the number of the predicted results falling in a deviation of compared with experimental results. Theoretically, the higher R^2 and lowest *RMSE* and *IAE* indicated the good prediction performance of proposed models, while $\alpha 20-\text{index}$ was expected to 1 in the perfect prediction models.

4.2 Existing prediction models for compressive strength of confined concrete

In this section, four existing models proposed by Richart [5], Mander [7], Saatcioglu [10] and Legeron [3] for predicting the compressive strength of confined concrete were reviewed, listed in Table.3. In Table.3, the existing models for evaluating the compressive strength of concrete confined with stirrups were proposed by considering the effects of the compressive strength of concrete, the volumetric ratio and the yield strength of stirrups, which ignored the effects of the aspect ratio of specimens, the spacing and diameter of spiral stirrups, and the ratio of longitudinal reinforcements. On the other hand, those existing models were proposed based on a set of specific experimental results, when the new test data sets were introduced, the models may not performed well.

Table.3 Existing prediction models for compressive strength of confined concrete

Reference	Equations
Richart [5]	$f_{\text{cc}} = f_{\text{c}} + 2.05\rho_{\text{sv}} f_{\text{yv}}$
Mander [7]	$f_{\text{cc}} = f_{\text{c}}(-1.254 + 2.254\sqrt{1+7.94k_{\text{e}} f_{\text{yv}}\rho_{\text{sv}}/2f_c} - k_{\text{e}} f_{\text{yv}}\rho_{\text{sv}}/f_{\text{c}}$ $k_{\text{e}} = (1 - s/(2D))/(1-\rho_{\text{s}}))$
Saatcioglu [10]	$f_{\text{cc}} = f_{\text{c}} + k_1\rho_{\text{sv}} f_{\text{yv}}/2$ $k_1 = 6.7(\rho_{\text{sv}} f_{\text{yv}}/2)^{-0.17}$
Legeron [3]	$f_{\text{cc}} = f_{\text{c}}\left[1+2.4(I_{\text{e}})^{0.7}\right]$ $I_{\text{e}} = 0.5k_{\text{e}}\rho_{\text{sv}} f_{\text{yv}}/f_{\text{c}}$

Where, f_{cc} was the compressive strength of confined concrete; f_{c} was the compressive strength of concrete; ρ_{sv} was the volumetric ratio of stirrups; f_{yv} was the yield strength of stirrups; k_{e} was the effective confinement coefficient; s was the spacing of stirrups; D was the diameter of specimens; ρ_{s} was the ratio of longitudinal reinforcement; k_1 was the parameter related to the yield strength and the volumetric ratio of stirrups.

4.3 Results and discussion

Fig.5 showed the comparison of compressive strength of concrete confined with stirrups of existing and proposed prediction models (listed in Table.3) and experimental results. The 45 degree line indicated that the perfect predicted results, equaling the experimental results. It was obvious that the compressive strength of concrete confined with stirrups calculated form the all existing models was lower than the experiment results, which can be attributed to the effects of concrete strength on the shear strength of concrete were underestimated and the ultimate shear strength of concrete fluctuated heavily, the upper limited value of the compressive strength of concrete confined with stirrups was derived as the lower limited value of experimental results in existing models.

The predicted results from the proposed models were also compared with experimental results. In Fig.5, the scatter of proposed models in this study approximated to the experimental results. Moreover, Fig.6 showed that the histograms of the proposed models, demonstrating that the good distribution with the mean values of unity.

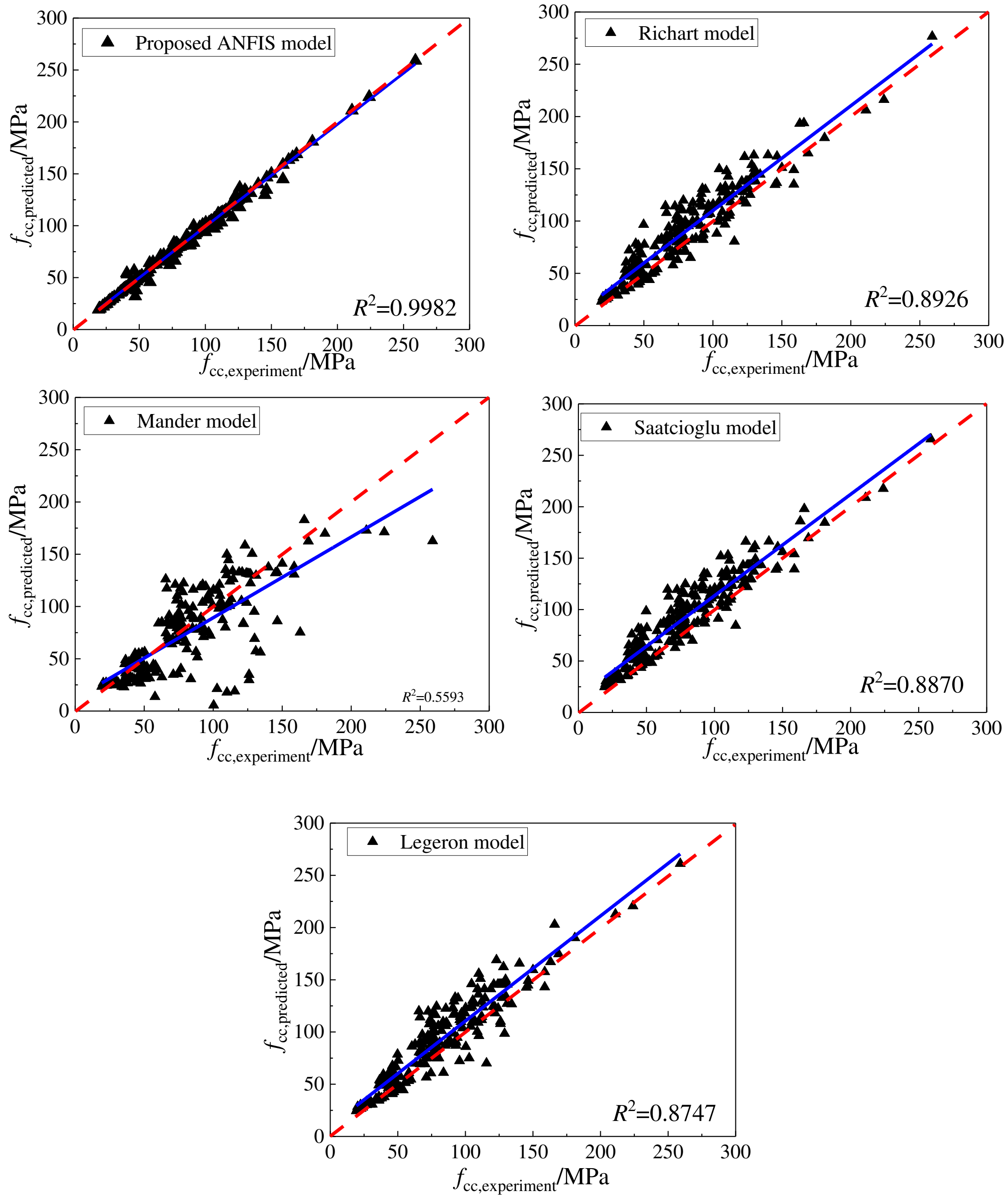


Fig.5 Comparison ultimate shear strength of concrete of prediction models and experimental results

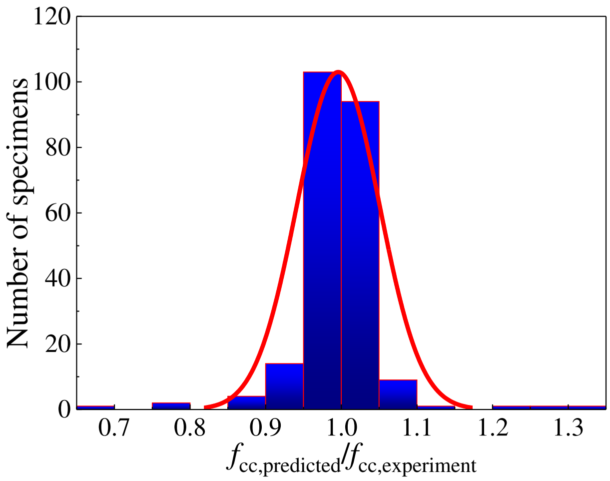


Fig.6 Histograms of the proposed models

Fig.7 showed that the box plot of $f_{cc,predicted}/f_{cc,experiment}$ with different prediction models and Table.4 listed the performance indicators of different models. It was highlighted that the proposed models were suitable for evaluating the compressive strength of concrete confined with stirrups due to the lowest *RMSE*, *IAE* and *SD* and the unity of mean values.

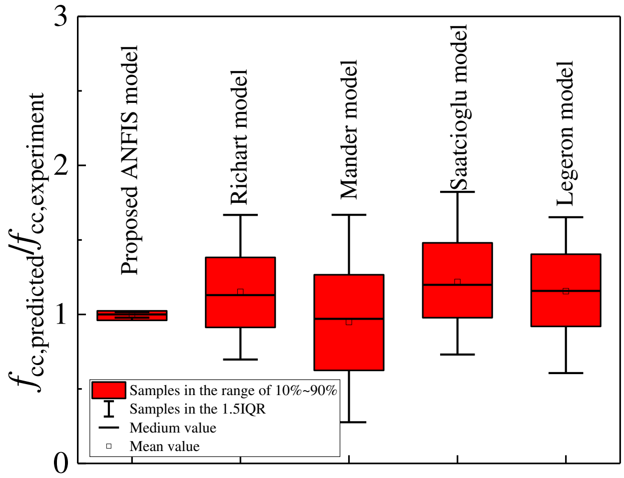


Fig.7 Box plot of $f_{cc,predicted}/f_{cc,experiment}$ with different prediction models

Table.4 Performance indicators of different prediction models

Models	R^2	*RMSE*	*IAE*	$f_{cc,predicted}/f_{cc,experiment}$		
				Mean	*SD*	$\alpha 20-\text{index}$
Proposed ANFIS model	0.9982	3.72	0.02	0.9959	0.05	0.99
Richart	0.9699	16.93	0.15	1.1510	0.20	0.63
Mander	0.8794	28.79	0.25	0.9486	0.30	0.63
Saatcioglu	0.9626	19.50	0.17	1.2172	0.21	0.50
Legeron	0.9659	18.14	0.16	1.1556	0.19	0.59

5. Parameter Analysis

In this study, the effects of the investigated parameters including the aspect ratio of specimens, the diameter, spacing, yield strength and volumetric ratio of stirrups, the ratio of longitudinal reinforcement and the compressive strength of concrete were performed based on the proposed ANFIS models. The mean values (listed in Table.1) of the investigated parameters were set as the basic values, while the certain parameter was varied from the minimum value to the maximum value. The outputs were obtained from the proposed ANFIS model.

5.1 Aspect ratio of specimens

Fig.8 showed the relationships between the compressive strength of confined concrete and the aspect ratio of specimens. The compressive strength of confined concrete increased firstly and then decreased with the increase of the aspect ratio of specimens.

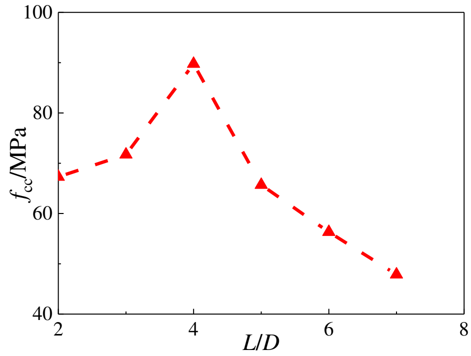


Fig.8 The compressive strength of confined concrete varied with the aspect ratio of specimens

5.2 Diameter of stirrups

Fig.9 showed that the compressive strength of confined concrete varied with the diameter of stirrups. The increase of the diameter of stirrups enhanced the confinement area of specimens. Thus, the increase of the diameter of stirrups enhanced the compressive strength of confined concrete.

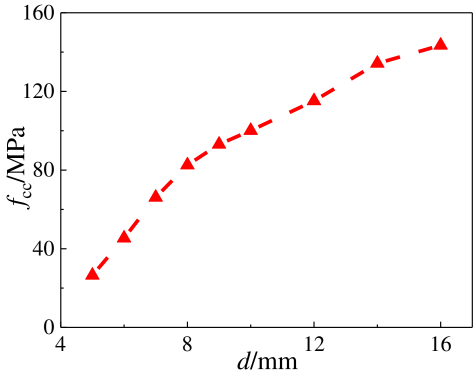


Fig.9 The compressive strength of confined concrete varied with the diameter of stirrups

5.3 Spacing of stirrups

Fig.10 presented that the compressive strength of confined concrete varied with the spacing of stirrups. The increase of the spacing of stirrups declined the effective confinement area of specimens and the longitudinal reinforcement tended to be bucking failure, which decreased the compressive strength of confined concrete.

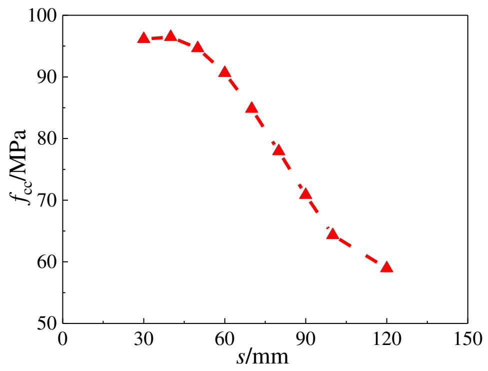


Fig.10 The compressive strength of confined concrete varied with the spacing of stirrups

5.4 Yield strength of stirrups

In Fig.11, the increase of the yield strength of stirrups enhanced the compressive strength of confined concrete. However, when the yield strength of stirrups exceeded 700MPa, the compressive strength of confined concrete increased slowly.

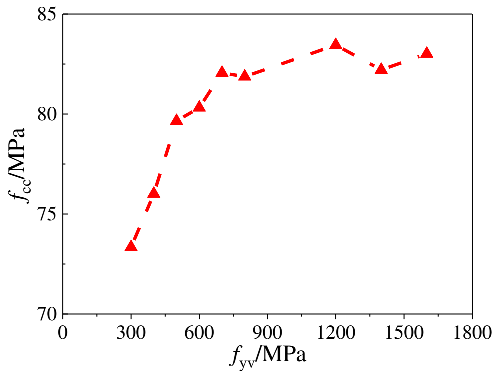


Fig.11 The compressive strength of confined concrete varied with the yield strength of stirrups

5.5 Volumetric ratio of stirrups

In Fig.12, the increment of the volumetric ratio of stirrups improved the compressive strength of confined concrete. The increment of the volumetric ratio of stirrups enhanced the lateral confinement of stirrups, which improved the compressive strength of confined concrete.

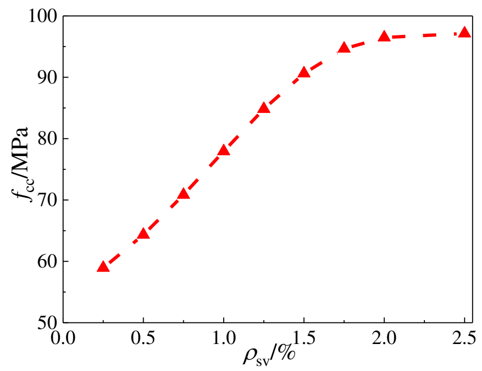


Fig.12 The compressive strength of confined concrete varied with the volumetric ratio of stirrups

5.6 Ratio of longitudinal reinforcement

Fig.13 showed that the compressive strength of confined concrete varied with the ratio of longitudinal reinforcement. When the ratio of longitudinal reinforcement was lower than 2%, the ratio of longitudinal reinforcement improved the compressive strength of confined concrete. When the ratio of longitudinal reinforcement was over 2%, the ratio of longitudinal reinforcement had the negative effects on the compressive strength of confined concrete.

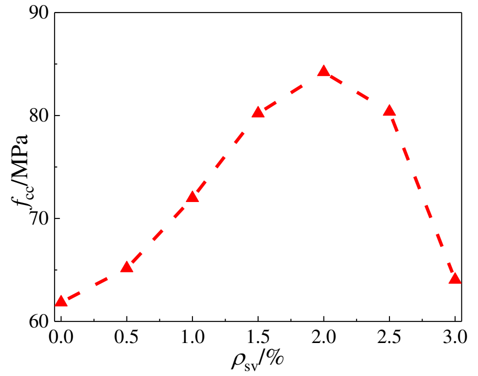


Fig.13 The compressive strength of confined concrete varied with the ratio of longitudinal reinforcement

5.7 Compressive strength of concrete

Fig.14 showed that the compressive strength of confined concrete varied with the compresisve strength of concrete. The compressive strength of confined concrete increased with the increase of concrete, while the increment of the compressive strength of confinement increased slowly when the compressive strength of concrete was more than 140 MPa.

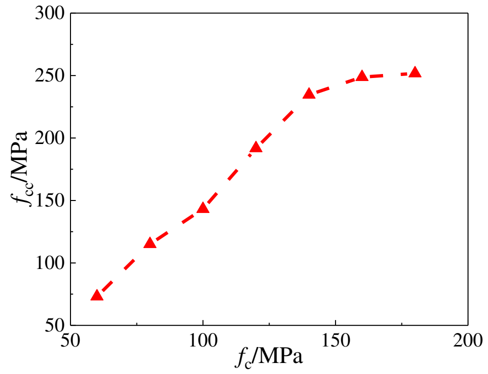


Fig.14 The compressive strength of confined concrete varied with the compressive strength of concrete

6. Conclusions

The aim of this paper was to evaluate the compressive strength of concrete confined with spiral stirrups. A reliable database consisting of 231-group experimental results collected from previous studies was established and the ANFIS model for evaluating the compressive strength of confined concrete was developed. The parametric analysis was performed based on the ANFIS model. The conclusions were drawn as following:

(1) The ANFIS model was adopted to predict the compressive strength of concrete confined with spiral stirrups, which has high prediction performance for both training and testing data sets.

(2) The ANFIS model proposed in this study has high reliability and high applicable in predicting the compressive strength of confined concrete by comparing with the existing models.

(3) Based on the proposed ANFIS model, the effects of influential parameters including the aspect ratio of specimens, the diameter, spacing, yield strength and volumetric ratio of stirrups, the ratio of longitudinal reinforcement, and the compressive strength of concrete on the compressive strength of confined concrete were analyzed.

Compliance with Ethical Standard：

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References

1. Nemecek, J.; Padevet, P.; Patzák, B. Effect of transversal reinforcement in normal and high strength concrete columns. *Materials and Structures*, **2005**, 38(7), 665-671.
2. Saatcioglu, M.; Razvi, S.R. High-Strength Concrete Columns With Square Sections Under Concentric Compression. *Journal of Structural Engineering*, **1998**, 124(12), 1438-1447.
3. Légeron, F.; Paultre, P. Uniaxial Confinement Model for Normal- and High-Strength Concrete Columns. *Journal of Structural Engineering*, **2003**, 129(2), 241-252.
4. Richart, F.E.; Brandtzæg, A.; Brown, R.L. Failure of plain and spirally reinforced concrete in compression. *Bull.university of Illiois Engrg.experiment Station*, **1929**, 26.
5. Richart, F.E.; Brandtzæg, A.; Brown, R.L. A study of the failure of concrete under combined compressive stresses. *Uni.illinois Eng.exp.st.bull*, **1928**, 185.
6. Mander, J.B.; Priestley, M.J.N.; Park, R. Observed Stress-Strain Behavior of Confined Concrete. *Journal of Structural Engineering*, **1988**, 114(8),1827-1849.
7. Mander, J.B.; Priestley, M.J.N.; Park, R. Theoretical Stress-Strain Model for Confined Concrete. *Journal of Structural Engineering*, **1988**, 114(8), 1804-1826.
8. Cusson D.; Paultre P. High-strength concrete columns confined by rectangular ties. *Journal of Structural Engineering*, 1994, 120(3): 783-804.
9. Bing L.; Park H. Stress-strain behavior of high-strength concrete confined by normal-strength transverse reinforcements. *ACI Structural Journal*, 2001, 98(3): 395-406.
10. Saatcioglu, M.; Razvi, S.R. Strength and Ductility of Confined Concrete. *Journal of Structural Engineering*, **1992**, 118(6), 1590-1607.
11. Sharma U.K.; Bhagava P.; Kaushik S.K. Behavior of confined high strength concrete columns under axial compression. *Journal of Advanced Concrete Technology*, 2005, 3(2): 267-281.
12. Wang G. Factors of binding effect on high-strength stirrup confined concrete under axial compression. *Earthquake Resistant Engineering and Retrofitting*, 2014, 36(2): 119-123,
13. Wei Y.; Wu Y.F. Compression behavior of concrete columns confined by high strength steel wire. *Construction and Building Materials*, 2014, 54(15): 443-453.
14. Li Y.Z.; Cao S.Y.; Liang H. Axial compressive behavior of concrete columns with grade 600 MPa reinforcing bars. *Engineering Structures*, 2018, 172(1): 497-507
15. Deng Z.C.; Yao J.S. Axial compression behavior of ultra-high performance concrete columns confined by high-strength stirrups. *Acta Materiae Compositae Sinica*, 2020, 10: 2590-2601.
16. Yalpir, S.; Ozkan, G. Knowledge-based FIS and ANFIS models development and comparison for residential real estate valuation. *International Journal of Strategic Property Management*, **2018**, 22(2), 110-118.
17. Akbarpour H.; Akbarpour M. Prediction of punching shear strength of two-way slabs using artificial neural network and adaptive neuro-fuzzy inference system. *Neural Computing and Application*, 2017, 28: 3273-3284.
18. Khademi F.; Jamal S.M.; Deshpande N.; Londhe S. Prediction of strength of recycled aggregate concrete using artificial neural network, adaptive neuro-fuzzy inference system and multiple linear regression. *International Journal of Sustainble Built Environment*, 2016, 5: 355-369.
19. Bilgehan M. A comparative study for the concrete compressive strength estimation using neural network and neuro-fuzzy modelling approaches. *Nondestructive Testing and Evaluation*, 2011, 26(01): 35-55.
20. Vakhshouri B.; Nejadi S. Prediction of compressive strength of self-compacting concrete by ANFIS models. *Neurocomputing*, 2018, 280(6):13-22.
21. Jiang J.S.R. ANFIS: adaptive-betwork-based fuzzy inference system. *IEEE Transactions on Systems, Man and Cybemetics*, 1993, 23(3): 665-685.
22. Sakai, J. Effect of lateral confinement of concrete and varying the axial load on seismic response of bridges, *Doctor of Engineering Dissertation, Department of Civil Engineering, Tokyo Institute of Technology, Tokyo*. **2001**
23. Sakai, J.; Kawashima, K.; Une, H.; Yoneda, K. Effect of tie spacing on the stress-strain relation of confined concrete, *Journal of Structural Engineering. ASCE*. **2000**,46 (3), 757-766.
24. Antonius. Performance of high-strength concrete columns confined by the medium strength of spirals and hoops, *Asian Journal Civil Engineering*. **2014**,15 (2), 245-258.
25. Assa, B.; Nishiyama, M.; Watanabe, F. New Approach for modeling confined concrete I: circular columns, *Journal of Structural Engineering. ASCE*. **2001**,127 (7), 743-750.

26. Bing, L. Strength and ductility of reinforced concrete members and frames constructed using high strength concrete, *Civil Engineering at the University of Canterbury, Christchurch, New Zealand.* **1993**.
27. Yang, X.; Zohrevand, P.; Mirmiran, A.; Behavior of ultrahigh-performance concrete confined by steel, *Journal of Materials in Civil Engineering*. **2016**, 28 (10), 04016113
28. Cusson, D.; Larrard, F.D.; Boulay, C.; Paultre, P. Strain localization in confined high-strength concrete columns, *Journal of Structural Engineering. ASCE*. **1998**,124 (9), 1055-1061.
29. Montgomery, D.L. Behavior of spirally reinforced high strength concrete columns under axial loading, *Doctoral and Master thesis, National Library of Canada*. **1996**.
30. TokIucu, M.T. Behavior of Reinforced Concrete Columns Confined with Circular Spirals and Hoops, *University of Toronto*. **1992**
31. Sheikh, S.A.; Toklucu, M.T. Reinforced Concrete Columns Confined by Circular Spirals and Hoops, *ACI Struct. J*. **1993**,90 (5): 542-553.
32. Silva, P.D. Effect of concrete strength on axial load response of circular columns, *McGill University, Canada*. **2000**.
33. Wang, Y.; Zhang, Z.; Zheng, W.Z, Zhu, A.P.; Zhao, J. Mechanical behavior of concrete columns confined by steel bar for prestressed concrete spiral hoops, *J. Harbin Institute. Tech*. **2013**,45 (4): 6-13
34. Razvi, S.R. Confinement of normal and high-strength concrete columns. *Univ. Ott, Can*. **1995.**
35. Wei, Y.; Wu, Y.F. Compression behavior of concrete columns confined by high strength steel wire. *Construction & Building Materials*, **2014**, 54(11):443-453.
36. Wang, W.; Zhang, M.; Tang, T. Behaviour of high-strength concrete columns confined by spiral reinforcement under uniaxial compression. *Construction & Building Materials*, **2017**, 154:496–503.
37. Marvel, L.; Doty, N.; Lindquist, W. Axial behavior of high-strength concrete confined with multiple spirals. *Engineering Structures*, **2014**, 60(2):68-80

Appendix

A database consisting of 231 experimental results of concrete confined with spiral stirrups collected from the previous studies was established.

Table.5 Experimental Data used for establishing Compressive Strength ANFIS Model

No.	L/D	Transverse reinforcements				ρ_s /%	f_c	f_{cc}	Reference
		d /mm	s /mm	f_{yv} /MPa	ρ_{sv} /%				
1	3.42	12	52	310	1.99	1.60	24.00	38.00	[6]
2	3.42	12	52	340	1.99	1.60	30.00	48.00	[6]
3	3.42	12	52	340	1.99	1.60	32.00	47.00	[6]
4	3.42	12	41	340	2.52	1.60	29.00	51.00	[6]
5	3.42	12	69	340	1.50	1.60	29.00	46.00	[6]
6	3.42	12	103	340	1.00	1.60	29.00	40.00	[6]
7	3.42	10	119	320	0.60	1.59	29.00	36.00	[6]
8	3.42	10	36	320	1.98	1.59	29.00	47.00	[6]
9	3.42	16	93	307	1.97	1.63	29.00	46.00	[6]
10	3.42	12	52	340	1.99	3.27	32.00	52.00	[6]
11	3.42	12	52	340	1.99	3.30	30.00	49.00	[6]
12	3.42	12	52	340	1.99	2.34	32.00	52.00	[6]
13	3.42	12	52	340	1.99	3.20	30.00	50.00	[6]
14	3.42	12	52	340	1.99	4.80	30.00	54.00	[6]
15	3.42	12	52	340	1.99	3.20	32.00	52.00	[6]
16	3.24	6.4	120	376	0.57	1.18	24.60	29.60	[22]
17	3.24	6.4	60	376	1.16	1.18	24.60	29.40	[22]
18	3.24	6.4	40	376	1.71	1.18	24.60	35.90	[22]
19	3.24	9.0	240	376	0.57	1.18	24.60	31.10	[22]
20	3.24	9.0	120	376	1.14	1.18	24.60	36.00	[22]
21	3.24	9.0	80	376	1.71	1.18	24.60	36.10	[22]

22	3.21	6.4	20	363	2.26	1.85	21.00	35.40	[23]
23	3.21	6.4	30	363	1.51	1.85	21.00	29.70	[23]
24	3.21	6.4	40	363	1.14	1.85	21.00	27.00	[23]
25	3.21	6.4	60	363	0.75	1.85	21.00	24.00	[23]
26	3.21	6.4	80	363	0.57	1.85	21.00	22.80	[23]
27	3.21	6.4	120	363	0.38	1.85	21.00	19.80	[23]
28	3.21	6.4	160	363	0.28	1.85	21.00	19.30	[23]
29	3.21	9.0	40	363	2.26	1.85	21.00	33.80	[23]
30	3.21	9.0	60	363	1.51	1.85	21.00	27.80	[23]
31	3.21	9.0	80	363	1.13	1.85	21.00	25.40	[23]
32	3.21	9.0	120	363	0.75	1.85	21.00	22.30	[23]
33	3.21	9.0	160	363	0.57	1.85	21.00	20.10	[23]
34	3.21	11.0	60	363	2.26	1.85	21.00	34.10	[23]
35	3.21	11.0	80	363	1.70	1.85	21.00	26.70	[23]
36	3.21	11.0	120	363	1.13	1.85	21.00	22.40	[23]
37	3.21	11.0	160	363	0.85	1.85	21.00	20.30	[23]
38	5.00	6.25	35	488	4.38	3.60	51.80	80.99	[24]
39	5.00	6.25	35	488	4.38	3.60	63.20	97.95	[24]
40	5.00	5.5	35	315	3.19	3.60	63.20	74.36	[24]
41	5.00	5.5	55	315	2.03	3.60	63.20	65.77	[24]
42	5.00	6.25	35	488	4.38	3.60	75.30	122.07	[24]
43	5.00	6.25	35	587	4.38	3.60	75.30	121.79	[24]
44	5.00	6.25	55	587	2.79	3.60	75.30	106.84	[24]
45	2.07	6.25	28	1296	3.05	0	25.04	95.70	[25]
46	2.07	6.25	44	1296	1.92	0	25.04	57.83	[25]
47	2.07	6.25	20	1296	4.15	0	34.13	129.03	[25]
48	2.07	6.25	28	1296	3.04	0	34.13	100.34	[25]
49	2.07	6.25	47	1296	1.80	0	34.13	62.87	[25]
50	2.07	6.25	50	909	1.69	0	34.13	58.19	[25]
51	2.07	6.25	75	909	1.13	0	34.13	42.28	[25]
52	2.07	6.25	28	1296	3.05	0	41.38	109.94	[25]
53	2.07	6.25	44	1296	1.92	0	41.38	76.59	[25]
54	2.07	6.25	28	1296	3.05	0	49.75	125.98	[25]
55	2.07	6.25	44	1296	1.92	0	49.75	88.61	[25]
56	2.07	6.25	28	1296	3.02	0	64.40	134.25	[25]
57	2.07	6.25	28	1296	3.05	0	64.40	130.87	[25]
58	2.07	6.25	44	1296	1.92	0	64.40	96.74	[25]
59	2.07	6.25	28	1296	3.02	0	70.10	130.00	[25]
60	2.07	6.25	44	1296	1.92	0	70.10	91.18	[25]
61	2.07	6.25	21	1296	4.15	0	83.03	163.01	[25]
62	2.07	6.25	28	1296	3.01	0	83.03	129.74	[25]
63	2.07	6.25	47	1296	1.82	0	83.03	105.48	[25]
64	2.07	6.25	50	909	1.69	0	83.03	99.64	[25]
65	3.43	6	20	445	2.69	1.5	63.00	93.00	[26]
66	3.43	6	35	445	1.54	1.5	63.00	78.00	[26]
67	3.43	6	50	445	1.08	1.5	63.00	74.70	[26]
68	3.43	6	65	445	0.83	1.5	63.00	70.60	[26]
69	3.43	6	20	445	2.69	1.5	72.30	108.80	[26]
70	3.43	6	35	445	1.54	1.5	72.30	92.70	[26]
71	3.43	6	50	445	1.08	1.5	72.30	85.00	[26]
72	3.43	6	65	445	0.83	1.5	72.30	73.80	[26]
73	3.43	6.4	20	1318	2.94	1.5	52.00	126.00	[26]

74	3.43	6.4	35	1318	1.67	1.5	52.00	87.50	[26]
75	3.43	6.4	50	1318	1.17	1.5	52.00	68.50	[26]
76	3.43	6.4	20	1318	2.94	1.5	82.50	146.50	[26]
77	3.43	6.4	35	1318	1.67	1.5	82.50	106.80	[26]
78	3.43	6.4	50	1318	1.17	1.5	82.50	92.30	[26]
79	3.43	6.4	35	1318	1.68	1.5	35.20	115.60	[26]
80	3.43	6.4	53	1318	1.10	1.5	35.20	83.80	[26]
81	3.43	6.4	70	1318	0.84	1.5	35.20	71.10	[26]
82	2.04	5.1	51	414	1.65	0	151.00	169.00	[27]
83	2.04	5.1	25	414	3.37	0	151.00	181.00	[27]
84	2.04	5.1	13	414	6.48	0	151.00	211.00	[27]
85	2.04	7.6	38	414	5.05	0	151.00	166.00	[27]
86	2.04	7.6	25	414	7.68	0	151.00	224.00	[27]
87	2.04	7.6	13	414	14.80	0	151.00	259.00	[27]
88	3.45	6	36	580	2.20	0	112.00	127.00	[28]
89	3.45	6	36	580	2.20	0	112.00	126.00	[28]
90	3.45	6	36	580	2.20	0	66.00	94.00	[28]
91	3.45	6	36	580	2.20	0	92.00	113.00	[28]
92	3.45	5	51	588	1.10	0	92.00	112.00	[28]
93	2.22	6	36	580	2.20	0	112.00	131.00	[28]
94	6.94	6	36	580	2.20	0	112.00	121.00	[28]
95	3.26	6	29	580	2.20	0	112.00	124.00	[28]
96	3.47	6	18	580	4.30	0	112.00	140.00	[28]
97	3.45	5	51	588	1.10	0	112.00	127.00	[28]
98	3.47	6	36	580	2.20	2	112.00	125.00	[28]
99	3.45	6	36	580	2.20	4	112.00	127.00	[28]
100	4.00	11.3	41	522	1.17	3	69.70	93.00	[29]
101	4.00	11.3	53	522	3.62	3	69.70	86.50	[29]
102	4.00	11.3	79	522	2.43	3	69.70	91.20	[29]
103	4.00	11.3	109	522	1.76	3	69.70	75.20	[29]
104	4.00	8	41	666	2.23	3	69.70	76.40	[29]
105	4.00	8	53	666	1.73	3	69.70	75.80	[29]
106	4.00	8	79	666	1.16	3	69.70	78.20	[29]
107	4.00	8	109	666	0.84	3	69.70	76.40	[29]
108	4.00	5.7	41	583	1.17	3	69.70	87.70	[29]
109	4.00	5.7	53	583	0.91	3	69.70	79.40	[29]
110	4.00	11.3	64	522	3.77	3.1	69.70	85.90	[29]
111	4.00	9.5	43	508	3.96	3.1	69.70	83.50	[29]
112	4.00	9.5	64	508	2.66	3.1	69.70	77.00	[29]
113	4.00	9.5	86	508	1.98	3.1	69.70	74.10	[29]
114	4.00	8	64	666	1.79	3.1	69.70	68.10	[29]
115	4.00	6.4	43	646	1.76	3.1	69.70	72.30	[29]
116	4.00	6.4	64	646	1.18	3.1	69.70	66.90	[29]
117	4.00	6.4	86	646	0.88	3.1	69.70	60.40	[29]
118	4.00	4.8	43	692	0.96	3.1	69.70	62.80	[29]
119	4.00	11.3	43	522	5.61	3.1	89.80	104.60	[29]
120	4.00	11.3	64	522	3.77	3.1	89.80	94.60	[29]
121	4.00	11.3	86	522	2.81	3.1	89.80	78.60	[29]
122	4.00	9.5	43	508	3.96	3.1	89.80	92.40	[29]
123	4.00	9.5	64	508	2.66	3.1	89.80	85.50	[29]
124	4.00	9.5	86	508	1.98	3.1	89.80	77.90	[29]
125	4.00	8	43	666	2.67	3.1	89.80	91.60	[29]

126	4.00	8	64	666	1.79	3.1	89.80	72.50	[29]
127	4.00	8	86	666	1.33	3.1	89.80	66.40	[29]
128	4.00	6.4	43	646	1.76	3.1	89.80	76.30	[29]
129	4.00	6.4	64	646	1.18	3.1	89.80	74.00	[29]
130	4.00	6.4	86	646	0.88	3.1	89.80	73.30	[29]
131	4.00	4.8	43	692	1.74	3.1	89.80	65.60	[29]
132	4.00	11.3	56	452	2.38	2.3	35.90	51.90	[30,31]
133	4.00	11.3	76	452	1.75	2.3	35.90	48.50	[30,31]
134	4.00	11.3	112	452	1.19	2.3	35.90	41.50	[30,31]
135	4.00	11.3	152	452	0.88	2.3	35.90	43.00	[30,31]
136	4.00	10.1	56	607	1.89	2.3	35.90	44.60	[30,31]
137	4.00	10.1	76	607	1.39	2.3	35.90	47.90	[30,31]
138	4.00	10.1	112	607	0.95	2.3	35.90	46.70	[30,31]
139	4.00	5.7	56	593	0.60	2.3	35.90	46.10	[30,31]
140	4.00	11.3	79	452	2.55	1.5	35.50	42.80	[30,31]
141	4.00	11.3	109	452	1.85	1.5	35.50	38.90	[30,31]
142	4.00	11.3	41	607	4.91	1.5	35.50	49.80	[30,31]
143	4.00	10.1	53	607	3.02	1.5	35.50	46.50	[30,31]
144	4.00	10.1	79	607	2.03	1.5	35.50	43.80	[30,31]
145	4.00	10.1	109	607	1.47	1.5	35.50	36.50	[30,31]
146	4.00	5.7	41	593	1.23	1.5	35.50	41.30	[30,31]
147	4.00	5.7	53	593	0.95	1.5	35.50	41.00	[30,31]
148	4.00	10.1	64	607	3.36	3.1	34.90	46.00	[30,31]
149	4.00	6.4	64	629	1.32	3.1	34.90	40.30	[30,31]
150	4.00	6.4	64	629	1.32	3.1	34.90	38.90	[30,31]
151	4.00	6.4	86	629	0.98	3.1	34.90	35.90	[30,31]
152	4.00	6.4	43	629	1.96	3.1	34.90	46.00	[30,31]
153	4.00	6.4	43	629	1.96	3.1	34.90	44.80	[30,31]
154	4.00	6.4	43	629	1.96	3.1	34.90	46.00	[30,31]
155	4.00	4.8	43	605	1.01	3.1	34.90	40.60	[30,31]
156	5.25	11.3	100	440	1.40	2.6	35.50	47.00	[32]
157	5.25	9.5	100	560	1.00	2.6	35.50	47.70	[32]
158	5.25	11.3	100	440	1.40	2.6	39.50	56.60	[32]
159	5.25	9.5	100	560	1.00	2.6	39.50	58.10	[32]
160	5.25	11.3	75	440	1.86	2.6	59.60	67.10	[32]
161	5.25	9.5	80	560	1.24	2.6	59.60	67.80	[32]
162	5.25	11.3	45	440	3.11	2.6	119.90	109.90	[32]
163	5.25	9.5	50	560	1.99	2.6	119.90	111.10	[32]
164	5.25	11.3	35	440	4.00	2.6	125.40	123.00	[32]
165	5.25	9.5	40	560	2.48	2.6	125.40	128.20	[32]
166	5.00	9	70	1034	2.42	1.44	27.20	44.10	[33]
167	5.00	9	80	1034	2.12	1.44	27.20	39.30	[33]
168	5.00	9	100	1034	1.70	1.44	41.50	50.30	[33]
169	5.00	9	200	1034	0.85	1.44	41.50	43.40	[33]
170	5.00	9	70	768	2.42	1.44	27.20	42.80	[33]
171	5.00	9	80	768	2.12	1.44	27.20	37.10	[33]
172	5.00	9	100	768	1.70	1.44	41.50	48.50	[33]
173	5.00	9	200	768	0.85	1.44	41.50	42.70	[33]
174	5.00	7	50	726	2.05	1.44	27.20	45.30	[33]
175	5.00	7	60	726	1.71	1.44	27.20	40.00	[33]
176	5.00	7	100	726	1.03	1.44	41.50	44.70	[33]
177	5.00	7	200	726	0.51	1.44	41.50	41.70	[33]

178	5.00	7	50	1027	2.05	1.44	27.20	47.50	[33]
179	5.00	7	60	1027	1.71	1.44	27.20	41.50	[33]
180	5.00	7	100	1027	1.03	1.44	41.50	46.10	[33]
181	5.00	7	200	1027	0.51	1.44	41.50	42.20	[33]
182	6.70	6.3	135	660	0.41	0	60.00	70.20	[34]
183	6.70	11.3	135	400	1.35	0	60.00	73.20	[34]
184	6.70	6.3	70	660	0.80	0	60.00	80.40	[34]
185	6.70	6.3	70	660	0.80	0	60.00	79.20	[34]
186	6.70	6.3	70	660	0.80	3.27	60.00	72.60	[34]
187	6.70	6.3	135	660	0.41	3.27	60.00	66.60	[34]
188	6.70	6.3	70	660	0.80	0	124.00	145.10	[34]
189	6.70	11.3	135	400	1.35	0	124.00	158.70	[34]
190	6.70	11.3	60	400	3.05	0	124.00	158.70	[34]
191	6.70	6.3	60	660	0.93	0	124.00	146.30	[34]
192	6.70	7.5	60	1000	1.32	0	124.00	150.00	[34]
193	6.70	7.5	60	1000	1.32	0	92.00	120.50	[34]
194	6.70	11.3	60	400	3.05	0	92.00	124.20	[34]
195	6.70	7.5	100	1000	0.79	0	92.00	112.20	[34]
196	6.70	7.5	60	1000	1.32	3.27	92.00	104.90	[34]
197	6.70	7.5	100	1000	0.79	3.27	92.00	97.50	[34]
198	6.70	11.3	100	400	1.83	0	92.00	111.30	[34]
199	6.70	6.3	100	660	0.56	0	92.00	104.00	[34]
200	6.70	6.3	70	660	0.80	0	92.00	109.50	[34]
201	6.70	11.3	135	400	1.35	0	92.00	104.90	[34]
202	2.00	3	-	-	0	0	36.40	36.50	[35]
203	2.00	3	10	1803	1.40	0	36.40	102.80	[35]
204	2.00	3	20	1803	0.72	0	36.40	74.50	[35]
205	2.00	3	30	1803	0.48	0	36.40	59.70	[35]
206	2.00	3	40	1803	0.36	0	36.40	55.70	[35]
207	2.50	8	55	515	1.40	1.40	85.20	79.90	[36]
208	2.50	8	80	515	0.97	1.40	85.20	82.30	[36]
209	2.50	8	110	515	0.70	1.40	85.20	75.20	[36]
210	2.50	8	160	515	0.48	1.40	85.20	74.50	[36]
211	1.67	8	55	515	1.40	1.40	85.20	76.90	[36]
212	3.33	8	55	515	1.40	1.40	85.20	85.30	[36]
213	2.50	8	55	515	1.40	1.40	101.30	100.20	[36]
214	2.50	8	80	515	0.97	1.40	101.30	97.20	[36]
215	2.50	8	110	515	0.70	1.40	101.30	96.20	[36]
216	2.50	8	160	515	0.48	1.40	101.30	95.90	[36]
217	1.67	8	55	515	1.40	1.40	101.30	90.70	[36]
218	3.33	8	55	515	1.40	1.40	101.30	103.30	[36]
219	2.50	8	55	515	1.40	1.40	118.30	114.10	[36]
220	2.50	8	80	515	0.97	1.40	118.30	109.70	[36]
221	2.50	8	110	515	0.70	1.40	118.30	114.50	[36]
222	2.50	8	160	515	0.48	1.40	118.30	112.10	[36]
223	1.67	8	55	515	1.40	1.40	118.30	109.00	[36]
224	3.33	8	55	515	1.40	1.40	118.30	118.80	[36]
225	2.86	9.5	50	467	2.10	1.60	67.30	76.00	[37]
226	2.86	9.5	40	467	2.60	2.00	67.30	75.50	[37]
227	2.86	9.5	50	467	2.10	2.00	67.30	77.90	[37]
228	2.86	9.5	55	467	1.90	2.00	67.30	66.10	[37]
229	2.86	9.5	60	467	1.70	2.00	67.30	68.70	[37]

230	2.86	9.5	50	467	2.10	2.40	67.30	69.30	[37]
231	2.86	9.5	50	467	2.10	2.80	67.30	77.00	[37]