CERTIFICATE

PRESENTED TO

Ngudiyono

In recognition and appreciation of your contributions as a **PRESENTER** at the 1st Mandalika International Multi-Conference on Science and Engineering (MIMSE) organized by the University of Mataram and Esa Unggul University

Lombok, Indonesia, September 14th , 2022

Dr. Nur Kaliwantoro, ST., MT.

General Chairman of the 1st MIMSE 2022

Peer-Review Statements

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All of the articles in this proceedings volume have been presented at the 1st MIMSE 2022 on September 14, 2022 in Mataram, Indonesia. These articles have been peer reviewed by the members of the Scientific Committee and approved by the Editor-in-Chief, who affirms that this document is a truthful description of the conference's review process.

1 Review Procedure

The reviews were single-blind. Each submission was examined by at least 1 reviewer independently.

The conference submission management system was *Easychair*.

The submissions were first screened for generic quality and suitableness. After the initial screening, they were sent for peer review by matching each paper's topic with the reviewers' expertise, taking into account any competing interests. A paper could only be considered for acceptance if it had received favourable recommendations from at least one reviewer.

Authors of a rejected submission were given the opportunity to revise and resubmit after addressing the reviewers' comments. The acceptance or rejection of a revised manuscript was final.

2 Quality Criteria

Reviewers were instructed to assess the quality of submissions solely based on the academic merit of their content along the following dimensions:

1. Pertinence of the article's content to the scope and themes of the conference;
2. Clear demonstration of originality, novelty, and timeliness of the research;
3. Soundness of the methods, analyses, and results;
4. Adherence to the ethical standards and codes of conduct relevant to the research field;
5. Clarity, cohesion, and accuracy in language and other modes of expression, including figures and tables.

B. Anshari—Editor-in-Chief the 1st MIMSE 2022_CA.

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In addition, all of the articles have been checked for textual overlap in an effort to detect possible signs of plagiarism by the publisher. We use Turnitin to find the similarity index. We set to exclude the bibliography and similarity that is less than 3% in this plagiarism checking. The accepted papers are the papers that the similarity index is below or equal 25%.

3 Key Metrics

Total submissions	25
Number of articles sent for peer review	25
Number of accepted articles	21
Acceptance rate	84%
Number of reviewers	16

4 Competing Interests

Neither the Editor-in-Chief nor any member of the Scientific Committee declares any competing interest.

Series: Advances in Engineering Research

Proceedings of the First Mandalika International Multi-Conference on Science and Engineering 2022, MIMSE 2022 (Civil and Architecture)

PREFACE

Conference name: Proceedings of the First Mandalika International Multi-Conference on Science and Engineering 2022, MIMSE 2022 (Civil and Architecture)
Date: 14-15 September 2022
Location: Mataram, Indonesia (Hybrid)
Website: https://mimse.unram.ac.id/

The 1st Mandalika International Multi-Conference on Science and Engineering 2022— Track Civil Engineering and Architecture is designed as an environment for researchers to discuss the current state of the science and technology in industry, university and companies. The conference is held hybrid at the Hotel Lombok Raya, Lombok, NTB, Indonesia, on September 14, 2022. This conference is organized by the Faculty ofEngineering, University of Mataram, West Nusa Tenggara, in collaboration with the University of Esa Unggul Jakarta. The MIMSE 2022 has theme of “smart and green technology for a better life”.

The articles of the 1st MIMSE 2022—Civil Engineering and Architecture Track come from seven countries all over the world. After peer-review, 21 papers were selected to be published in the Atlantis Publisher. Several excellent keynote and invited speakers presented state-of-the art findings in the science and engineering. This conference is the result of the hard work, support and dedication of a number of parties. We wish to thank all the committee members who together make the conference possible. We also want to thank our partners for the funding of the conference.

Yours sincerely,
Nur Kaliwantoro
1st MIMSE 2022 Chair
October 2022

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Application of the Adaptive Neuro Fuzzy Inference System (ANFIS) to Predict Ultimate Bearing Capacity of Footing on Granular Soil

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Abstract. The ultimate bearing capacity is an important parameter in the footing foundation design. Several classical methods are often used to analyze the bearing capacity of a footing foundation. However, the results of this analysis always give less accurate results than the experiment. In this manuscript, an Adaptive Neuro Fuzzy Inference System (ANFIS) model was built for predicting ultimate bearing capacity of footings on granular soil. Learning process data consists of input and output. The five input parameters used for the model development in this study are width (B), depth (D_f), shape factor (L/B) of footing, unit weight (γ) and friction angle (ϕ) of soil and the output is ultimate bearing capacity (q_u). The results of the analysis showed that the ANFIS model has a good level of accuracy compared with the experiment, where the correlation coefficient (R^2) for testing data was 0.98 and the Root Mean Square Error (RMSE) was 32.11 kN/m^2. This demonstrates that the ANFIS model developed is accurate in predicting the ultimate bearing capacity of footings on granular soil.

Keywords: footing · granular soil · ultimate bearing capacity · ANFIS

1 Introduction

Footing is one type of shallow foundation that is widely used in reinforced concrete building structures. The ultimate bearing capacity is an essential requirement for foundation design. Several classical methods are often used to analyze the bearing capacity of foundations, namely the theories of Terzaghi, Meyerhof, Vesic [1–3] and others. However, the results of this analysis always give less accurate results than the experiment. This is due to the uncertain nature of the soil and the difficulty of experimental testing in the laboratory and in situ, so it is necessary to look for alternative bearing capacity prediction methods to obtain more accurate results.

The development of soft computing, especially in the field of artificial intelligence, enables computer machines to solve problems such as those done by humans. Some artificial intelligence which has been applied in the field of civil engineering is artificial neural networks (ANN) and fuzzy logic (FL) [4]. However, the use of the ANN method has several weaknesses, namely It takes a lot of iterations in the training process to process

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the neural network, so sometimes the results obtained become less accurate. While the weakness in the fuzzy logic (FL) method requires an optimization method, namely by how to try (trial and error) in determining the membership function to obtain an optimal membership function. Hence, by combining ANN and FL methods into the Adaptive Neuro Fuzzy Inference System method (ANFIS), where membership functions and rules (IF THEN) can be determined from data input automatically through the learning process, this model is expected to be able to reduce the weaknesses of each method, so that the predictions generated will be more accurate. In this study, the ANFIS method has been used for predicting the ultimate bearing capacity of a footing on granular soil.

2 Theory

2.1 Ultimate Bearing Capacity

The highest resistance to pressure applied through the foundation to the soil without causing shear failure in the soil may be considered the ultimate bearing capacity of the soil. Terzaghi was the first to introduce a theory for estimating the ultimate bearing capacity of shallow foundations. He invented the following semi-empirical equation to express the ultimate bearing capacity of a strip footing [5]:

$$q_u = c\,Nc\left(1 + 0.3\frac{B}{L}\right) + D_f\,\gamma\,N_q + 0.5\,\gamma\,B\,N_\gamma\left(1 - 0.2\frac{B}{L}\right) \tag{1}$$

$$N_c = \text{cotg}\,\phi\left(\frac{a^2}{2\cos^2(45 + \phi/2)} - 1\right) \tag{2}$$

$$N_q = \left(\frac{a^2}{2\cos^2(45 + \phi/2)} - 1\right)N_c\,\text{tg}\,\phi + 1 \tag{3}$$

$$N_\gamma = \left(\frac{\text{tg}\,\phi}{2}\right)\left(\frac{K_{p\gamma}}{\cos^2\phi} - 1\right) \tag{4}$$

$$a = e^{\left(\frac{3}{4}\pi - \frac{\phi}{2}\right)\text{tg}\,\phi} \tag{5}$$

$$K_{p\gamma} = 3\tan^2\left[45^\circ + \frac{1}{2}(\phi + 33^\circ)\right] \tag{6}$$

where:
q_u: ultimate bearing capacity (kN/m^2)
N_c, N_q, N_γ: factors of bearing capacity
c: cohesion (kN/m^2)
φ: friction angel (^{o})
γ: unit weight of soil (kN/m^3)
$K_{p\gamma}$: passive earth pressure coefficient
B: width of footing foundation (m)
L: length of footing foundation (m)
D_f: depth of footing foundation (m)

2.2 Adaptive Neuro Fuzzy Inference System (ANFIS)

The Adaptive Neuro Fuzzy Inference System (ANFIS) was first introduced by Jang in 1993 [6], is a combination of Artificial Neural Network (ANN) and Fuzzy Inference System (FIS) that uses the Takagi and Sugeno model. By using a hybrid learning procedure (a combination of the Backward-Propagation Gradient Descent method (BPGD) and Least Squares Estimator (LSE), ANFIS can build a mapping input and output that is both based on human knowledge with fuzzy rules IF THEN with the right membership function. The modeling process with ANFIS Tools in MATLAB Student Version R2014a is divided into three parts, namely the training, testing, and checking process [7]. The principle of the training process is to learn about data in order to obtain results in accordance with the targets on the data. The testing process is the process of testing the accuracy of the models that have been obtained from the training process.

3 Research Methodology

3.1 Data Collection

Data collection must have been carried out prior to modeling. The ANFIS model was created utilizing data from previous research on the ultimate bearing capacity test, including Muhs et al.; Weiβ; Muhs and Weiβ; Briaud and Gibbens; Gandhi; Golder and Eastwood [8–15], also available in reference [5]. The obtained data is then grouped into data that will be input and output. There are 97 data series [8–13] for training (Table 1) and 9 data [14, 15] for the testing process (Table 2). The following five independent variables were treated as input data: width (B), depth (D_f), shape factor (L/B) of footing, unit weight of soil (γ) and friction angle (ϕ) of soil, while the output was the ultimate bearing capacity (q_u) of footing.

3.2 Performance ANFIS Model

To find out the reliability and the level of accuracy of the ANFIS model, the error value is calculated with the correlation coefficient (R^2) and Root Mean Square Error (RMSE) in Eqs. (7) and (8):

$$R^2 = 1 - \frac{\sqrt{\sum_{i=1}^{n}(t_i - y_i)^2}}{\sqrt{\sum_{i=1}^{n}(t_i - \bar{t})^2}} \tag{7}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(t_i - y_i)^2}{n}} \tag{8}$$

where:
t_i: experiment data i
y_i: ANFIS model data i
$\bar{t}$: average experiment data
n: number of data

Table 1. Data training.

No Data	B (m)	D_f (m)	L/B	γ (kN/m^3)	ϕ (°)	q_u (kN/m^2)	Ref.
1	0.6	0.3	2	9.85	34.9	270	[8]
2	0.6	0	2	10.2	37.7	200	
3	0.6	0.3	2	10.2	37.7	570	
4	0.6	0	2	10.85	44.8	860	
5	0.6	0.3	2	10.85	44.8	1760	
6	0.5	0	1	10.2	37.7	154	[9]
7	0.5	0	1	10.2	37.7	165	
8	0.5	0	2	10.2	37.7	203	
9	0.5	0	2	10.2	37.7	195	
10	0.5	0	3	10.2	37.7	214	
11	0.52	0	3.85	10.2	37.7	186	
12	0.5	0.3	1	10.2	37.7	681	
13	0.5	0.3	2	10.2	37.7	542	
14	0.5	0.3	2	10.2	37.7	530	
15	0.5	0.3	3	10.2	37.7	402	
16	0.52	0.3	3.85	10.2	37.7	413	
17	0.5	0	1	11.7	37	111	[10]
18	0.5	0	1	11.7	37	132	
19	0.5	0	2	11.7	37	143	
20	0.5	0.013	1	11.7	37	137	
21	0.5	0.029	4	11.7	37	109	
22	0.5	0.127	4	11.7	37	187	
23	0.5	0.3	1	11.7	37	406	
24	0.5	0.3	1	11.7	37	446	
25	0.5	0.3	4	11.7	37	322	
26	0.5	0.5	2	11.7	37	565	
27	0.5	0.5	4	11.7	37	425	
28	0.5	0	1	12.41	44	782	
29	0.5	0	4	12.41	44	797	[10]
30	0.5	0.3	1	12.41	44	1940	
31	0.5	0.3	1	12.41	44	2266	

(*continued*)

Table 1. (*continued*)

No Data	B (m)	D_f (m)	L/B	γ (kN/m^3)	ϕ (°)	q_u (kN/m^2)	Ref.
32	0.5	0.5	2	12.41	44	2847	
33	0.5	0.5	4	12.41	44	2033	
34	0.5	0.49	4	12.27	42	1492	
35	0.5	0	1	11.77	37	123	
36	0.5	0	2	11.77	37	134	
37	0.5	0.3	1	11.77	37	370	
38	0.5	0.5	2	11.77	37	464	
39	0.5	0	4	12	40	461	
40	0.5	0.5	4	12	40	1140	
41	1	0.2	3	11.97	39	710	[11]
42	1	0	3	11.93	40	630	
43	0.991	0.711	1	15.8	32	1774	[12]
44	3.004	0.762	1	15.8	32	1019	
45	2.489	0.762	1	15.8	32	1158	
46	1.492	0.762	1	15.8	32	1540	
47	3.016	0.889	1	15.8	32	1161	
48	0.059	0.029	5.95	15.7	34	58.5	[13]
49	0.059	0.058	5.95	15.7	34	70.91	
50	0.059	0.029	5.95	16.1	37	82.5	
51	0.059	0.058	5.95	16.1	37	98.93	
52	0.059	0.029	5.95	16.5	39.5	121.5	
53	0.059	0.058	5.95	16.5	39.5	142.9	
54	0.059	0.029	5.95	16.8	41.5	157.5	
55	0.059	0.058	5.95	16.8	41.5	184.9	
56	0.059	0.029	5.95	17.1	42.5	180.5	
57	0.059	0.058	5.95	17.1	42.5	211	
58	0.094	0.047	6	15.7	34	74.7	
59	0.094	0.094	6	15.7	34	91.5	
60	0.094	0.047	6	16.1	37	104.8	
61	0.094	0.094	6	16.1	37	127.5	
62	0.094	0.047	6	16.5	39.5	155.8	

(*continued*)

Table 1. (*continued*)

No Data	B (m)	D_f (m)	L/B	γ (kN/m^3)	ϕ (°)	q_u (kN/m^2)	Ref.
63	0.094	0.094	6	16.5	39.5	185.6	
64	0.094	0.047	6	16.8	41.5	206.8	
65	0.094	0.094	6	16.8	41.5	244.6	
66	0.094	0.047	6	17.1	42.5	235.6	
67	0.094	0.094	6	17.1	42.5	279.6	
68	0.152	0.075	5.95	15.7	34	98.2	
69	0.152	0.15	5.95	15.7	34	122.3	
70	0.152	0.075	5.95	16.1	37	143.3	
71	0.152	0.15	5.95	16.1	37	176.4	
72	0.152	0.075	5.95	16.5	39.5	211.2	
73	0.152	0.15	5.95	16.5	39.5	254.5	
74	0.152	0.075	5.95	16.8	41.5	285.3	
75	0.152	0.15	5.95	16.8	41.5	342.5	
76	0.152	0.075	5.95	17.1	42.5	335.3	
77	0.152	0.15	5.95	17.1	42.5	400.6	
78	0.094	0.047	1	15.7	34	67.7	
79	0.094	0.094	1	15.7	34	90.5	
80	0.094	0.047	1	16.1	37	98.8	
81	0.094	0.094	1	16.1	37	131.5	
82	0.094	0.047	1	16.5	39.5	147.8	
83	0.094	0.094	1	16.5	39.5	191.6	
84	0.094	0.047	1	16.8	41.5	196.8	
85	0.094	0.094	1	16.8	41.5	253.6	
86	0.094	0.047	1	17.1	42.5	228.8	
87	0.094	0.094	1	17.1	42.5	295.6	
88	0.152	0.075	1	15.7	34	91.2	
89	0.152	0.15	1	15.7	34	124.4	
90	0.152	0.075	1	16.1	37	135.2	
91	0.152	0.15	1	16.1	37	182.4	
92	0.152	0.075	1	16.5	39.5	201.2	
93	0.152	0.15	1	16.5	39.5	264.5	
94	0.152	0.075	1	16.8	41.5	276.3	

(*continued*)

Table 1. (*continued*)

No Data	B (m)	D_f (m)	L/B	γ (kN/m^3)	ϕ (°)	q_u (kN/m^2)	Ref.
95	0.152	0.15	1	16.8	41.5	361.5	
96	0.152	0.075	1	17.1	42.5	325.3	
97	0.152	0.15	1	17.1	42.5	423.6	

Table 2. Data testing.

No Data	B (m)	D_f (m)	L/B	γ_t (kN/m^3)	ϕ (°)	q_u (kN/m^2)	Ref.
1	0.08	0	1	17.2	42.8	133	[14]
2	0.15	0	1	17.2	42.8	246	
3	0.05	0	1	17.2	42.8	109	[15]
4	0.08	0	1	17.1	42.8	130	
5	0.1	0	1	17.1	42.8	152	
6	0.15	0	1	17.1	42.8	214	
7	0.2	0	1	17.1	42.8	266	
8	0.25	0	1	17.1	42.8	333	
9	0.3	0	1	17.1	42.8	404	

4 Result and Discussion

4.1 Development ANFIS Model

The Adaptive Neuro Fuzzy Inference System (ANFIS) is a hybrid of ANN and FIS in which membership functions and rules IF THEN are automatically determined from data input through a learning process. Figure 1 and Fig. 2 show the FL and ANN Architect models, respectively. The ANFIS toolbox MATLAB Student Version program provides multiple membership functions for inputs: trimf, trapmf, gbellmf, gaussmf, gauss2mf, pimf, dsigmf, and psigmf [7]. Figure 3, 4, 5, 6 and 7 demonstrate the gbellmf membership function of the FIS model for input data, which are width (B), depth (D_f), shape factor (L/B) of footing, unit weight of soil (γ) and friction angle (ϕ) of soil, and Fig. 8 shows the rule IF THEN.

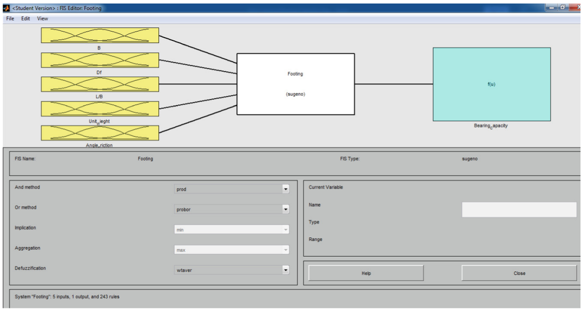

Fig. 1. FIS Model.

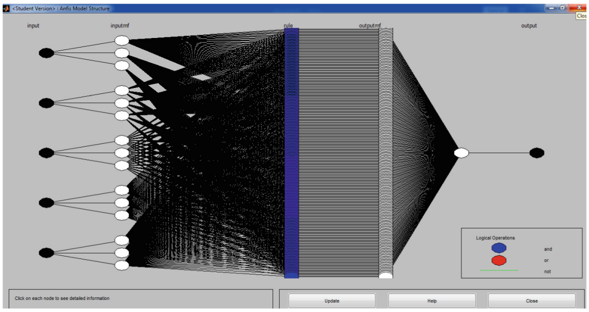

Fig. 2. ANN Architect model.

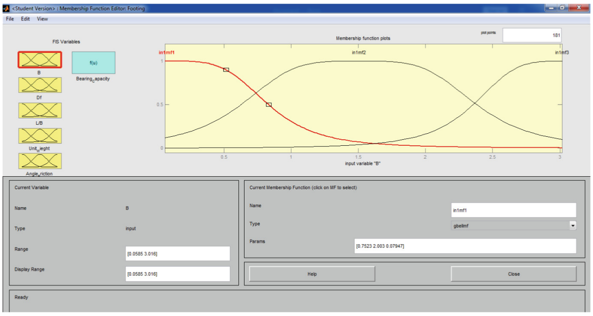

Fig. 3. Membership function width of footing (B).

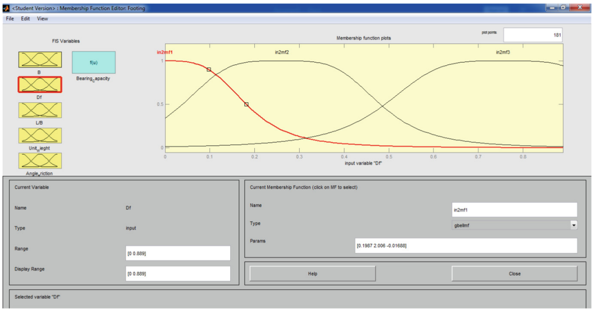

Fig. 4. Membership function depth of footing (D_f).

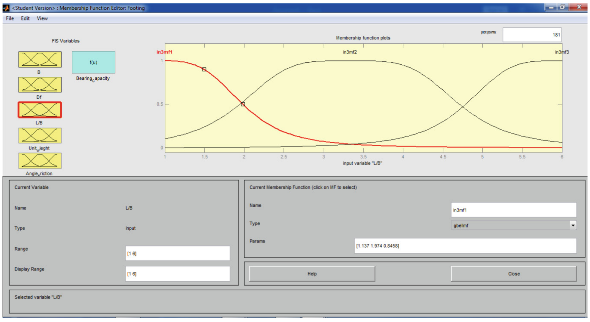

Fig. 5. Membership function shape factor of footing (L/B).

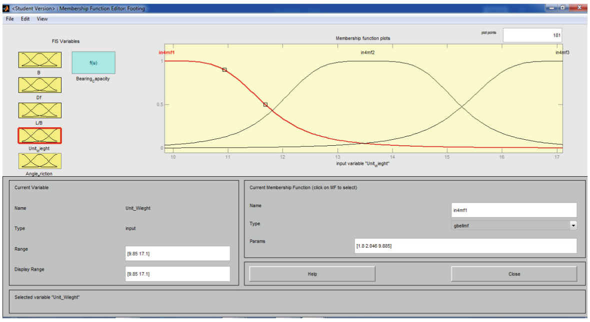

Fig. 6. Membership function unit weight of soil (γ).

4.2 Evaluation ANFIS Model

The results of the learning process were compared to the testing data to evaluate the performance of the constructed ANFIS model, as shown in Figs. 9 and 10. The correlation coefficient (R^2) for testing data was 0.98 with RMSE of 32.11 kN/m^2, indicating that the ANFIS model has a good level of accuracy.

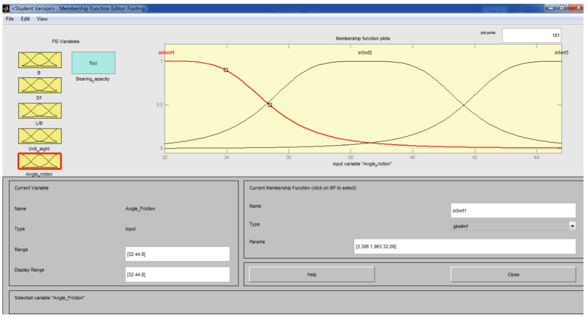

Fig. 7. Membership function friction angle of soil (ϕ).

Fig. 8. Rule IF THEN ANFIS model.

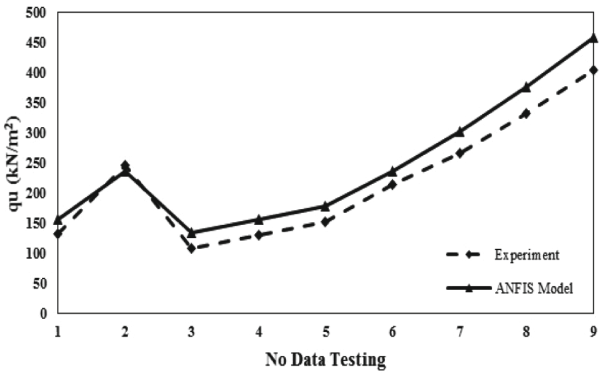

Fig. 9. Comparison of bearing capacity experiment and ANFIS model.

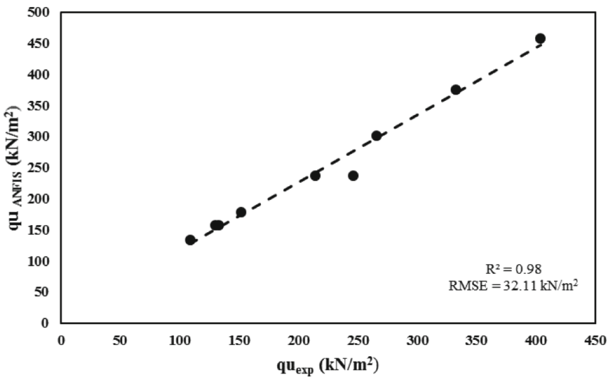

Fig. 10. Evaluation ANFIS model.

5 Conclusion

In this study, the ANFIS model was developed for predicting the ultimate bearing capacity of a footing on granular soil, where the parameter is important in the foundation design of a footing. The results of the analysis showed that the ANFIS model has a good level of accuracy compared with the experiment, where the correlation coefficient (R^2) for testing data was 0.98 with RMSE of 32.11 kN/m^2. This demonstrates that the ANFIS model developed is accurate in predicting the ultimate bearing capacity of footings on granular soil.

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