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GMDH-Network to Estimate the Punching Capacity of FRP-RC Slabs

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ABSTRACT

Determination of the punching shear capacity of FRP-reinforced concrete slabs was studied in this paper. A database including 81 pairs of data was collected and used. The method was considered in the paper, was group method of data handling (GMDH) which is one of the most structures which is used by researchers. The section area of the column, effective flexural depth of slab, the compressive strength of concrete, Young's modulus of the FRP slab and reinforcement ratio were used as input variables. The target of the model was also the determination of the ultimate punching capacity of the FRP-reinforced concrete flat slab (Target). Based on this dataset, ten polynomials specified and its coefficients were presented. All of these ten polynomials used for the considered prediction. The proposed GMDH structure also validate by several experimental data. The results indicated that group method of data handling (GMDH) is beneficial for the prediction of the punching shear capacity of slabs.

1. Introduction

Group Method of Data Handling (GMDH) which presented by Ivakhnenko [1] is a powerful method to create a mathematical network based on a multilayered perceptron-type network

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structure. The use of this method studied by many researchers in many fields of engineering. In Structural engineering, soft computing approaches such as ANN and also fuzzy systems are very popular and used for prediction [2–4] or FRP material [5]. GMDH as one of the soft computing approach GMDH is a useful method to create equations which can be used in the codes. An essential different between this type of network and other networks is the mathematical approach which can help to understand the way of the solution. GMDH is a neural network structure for function approximation of complex engineering problems. In this paper, punching shear capacity of FRP-reinforced concrete slabs was estimated by GMDH based on experimental data which were published in the literature.

2. Experimental data

To train the GMDH structure, the author used 81 pairs of data which were published by researchers [6–8]. The details of the database are presented in Table. 1. The section area of column (Input 1), effective flexural depth of slab (Input 2), compressive strength of concrete (Input 3), Young's modulus of the FRP slab (Input 4) and reinforcement ratio (Input 5) are considered as input parameters that determine the ultimate punching capacity of the FRP-reinforced concrete flat slab (Target). 69 data used for training phase of the selected GMDH and 12 remained data was used for validating the proposed structure.

Table 1
Range of experimental date.

Type	Input1	Input2	Input3	Input4	Input5	Target
Mean	625.000	131.000	38.600	48.200	0.810	329.000
Minimum	50.270	55.000	26.000	28.400	0.180	61.000
Maximum	2025.000	284.000	75.800	147.600	3.780	1600.000
Standard deviation	572.349	60.440	10.122	33.125	0.695	355.903

3. GMDH Network for prediction

Based on five inputs and one output, the best structure of GMDH for prediction of the considered goal had three layers and ten polynomials. This structure showed in Fig. 1. Each of this polynomial is a two-order polynomial with two variables which is defined by Eq. 1:

$$Y_n = c_1 + c_2 X_i + c_3 X_j + c_4 X_i^2 + c_5 X_j^2 + c_6 X_i X_j \qquad n=1, ..., 10 \tag{1}$$

where, X_i and X_j are the input variable *i* and *j*.

The coefficients of the polynomials for the proposed structure of GMDH presented in Table. 2. These values determined based on normal values between 0.1 to 0.9. It means that for any prediction by the proposed structure, first, the input values should be normalized. For this purpose, the author used the Eq. 2:

$$x_n = 0.8 \, \frac{x_{ex} - x_{min}}{x_{max} - x_{min}} + 0.1 \tag{2}$$

where x_n, x_{ex}, x_{min} and x_{max} are normalized, experimental, minimum and maximum values in the database respectively. It was clear that after calculating the normal value for the target, it can be simplicity converted to the real value.

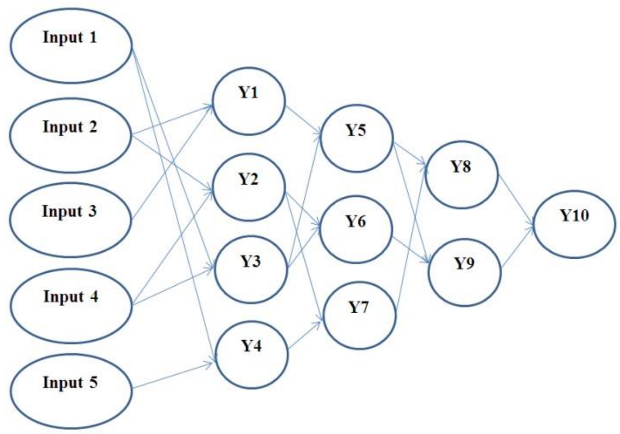

Fig. 1. The proposed GMDH structure.

Table 2
Coefficients of the polynomials for GMDH structure.

	Coefficients of the polynomials					
Polynomial	C1	C2	C3	C4	C5	C6
y1	-0.1331	0.8352	0.4037	-0.1833	-0.2475	0.3439
y2	0.3212	-0.1891	-0.9119	0.4542	0.5052	1.6049
y3	-0.2476	1.5969	0.7983	-1.1768	-0.7926	0.2705
y4	-0.0377	1.7376	-0.2021	-1.1957	0.2515	-0.4072
y5	0.1203	-0.0822	0.0031	-0.4463	-1.1091	3.5583
y6	0.0384	0.0215	0.5142	1.1856	-0.0094	-0.4107
y7	0.0835	0.6307	-0.3364	2.3476	2.7797	-4.2688
y8	0.0012	0.8388	0.1302	-0.3876	0.4114	0.0400
y9	0.0153	0.6031	0.2581	1.7816	2.2043	-3.8154
y10	0.0096	0.3101	0.6180	22.6804	21.9818	-44.6125

4. Results of the GMDH structure

As mentioned in section 2, the number of training data and test data in this paper were 69 and 12 respectively. The results of the proposed structure of the GMDH presented in Fig. 2-4.

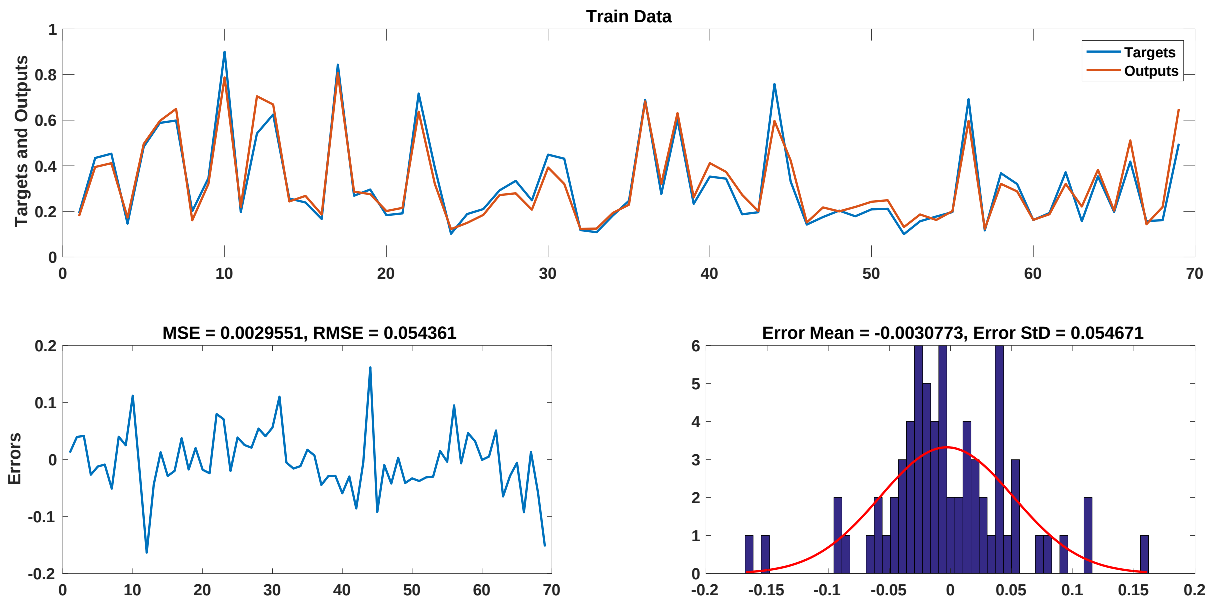

Fig. 2. The results for train data.

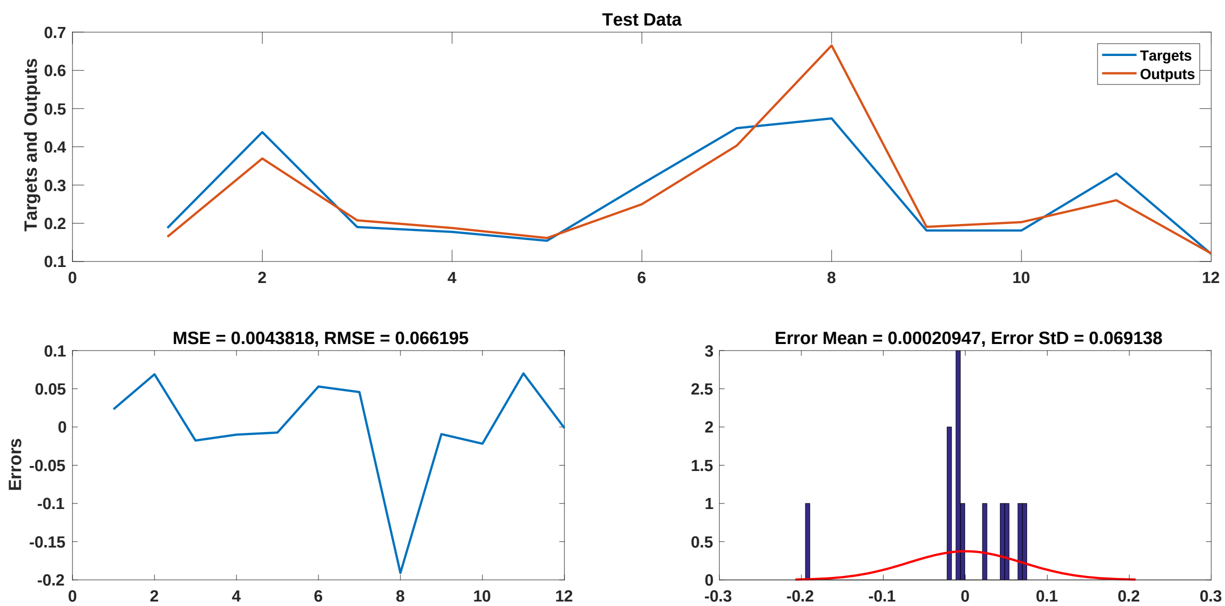

Fig. 3. The results for test data.

The results of the train and test data showed that GMDH could be used for estimating the considered capacity. The correlation coefficient (R2) for train and test were 0.96 and 0.89 which was showed that GMDH had suitable results. Scatter plots of train and test were presented in Fig. 5-6.

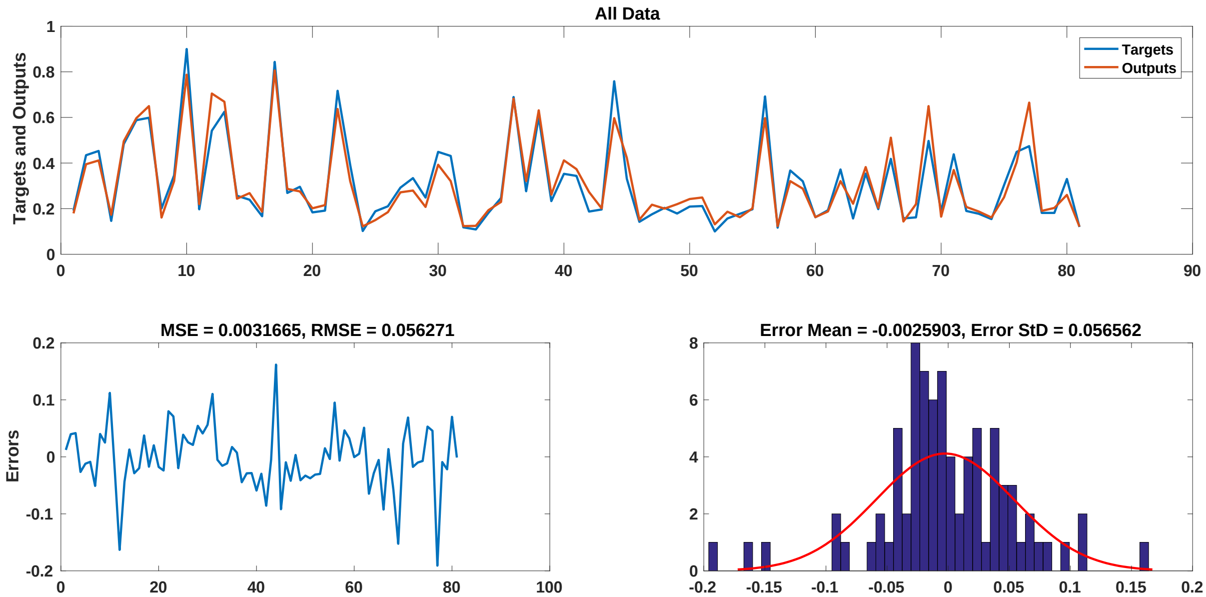

Fig. 4. The results for all data.

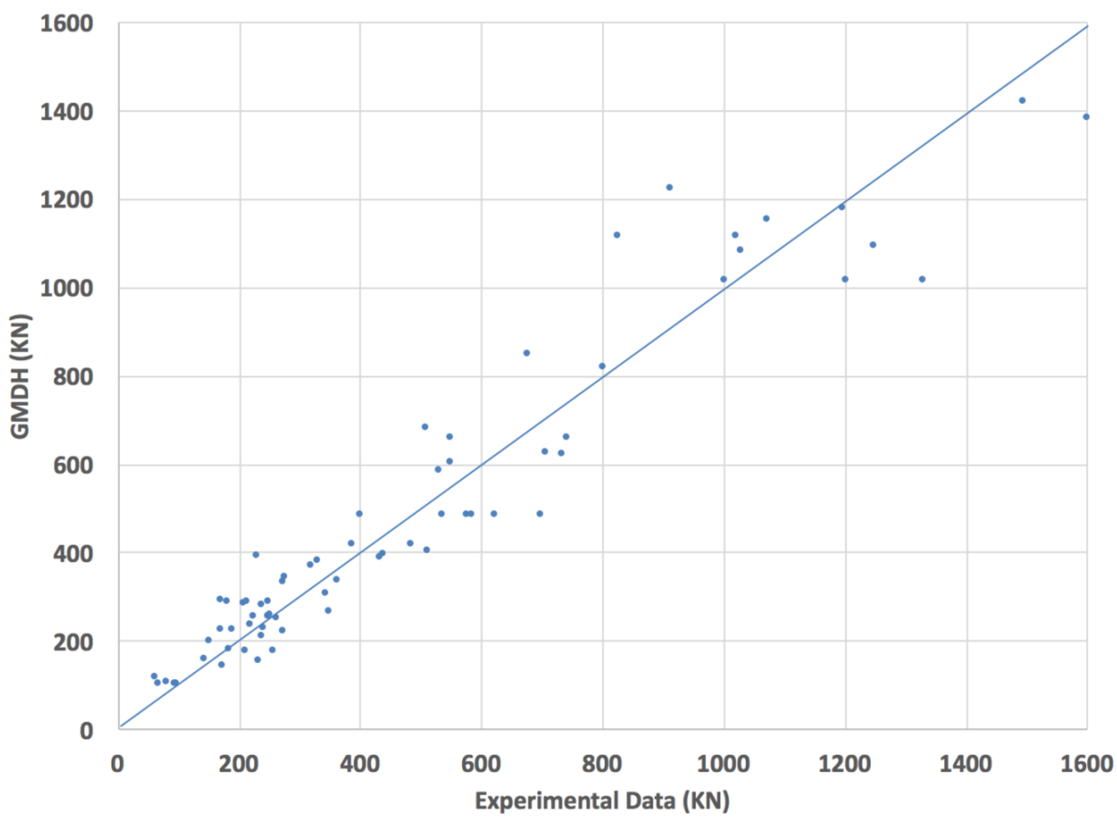

Fig. 5. Scatter plot for train data (R^2=0.96).

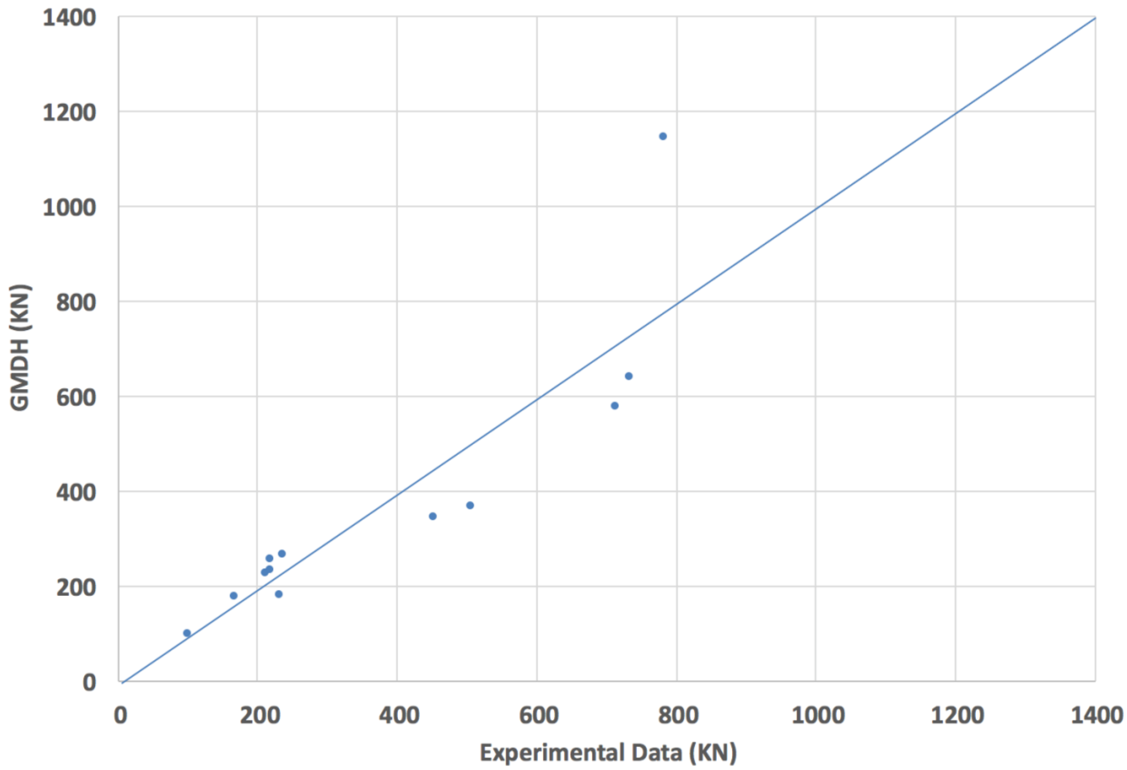

Fig. 6. Scatter plot for train data (R2=0.89).

It was clear from the figures 2 and 3 that it was clear that the ANN-GA had suitable results and can be used for the shear capacity prediction.

5. Conclusions

GMDH-neural network used to predict the punching shear capacity of RC-slabs in this paper. The proposed structure had five inputs and three layers. Each layer had several nodes which were included a two-order polynomial with two variables. The GMDH network trained based on experimental data and also validated. It was concluded that GMDH with a suitable accuracy could be used for considered prediction.

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