**Novel hybrid machine learning models for failure mode identification and shear strength prediction of rectangular hollow RC columns subjected to compressive and lateral loads**

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**1. Results of shear strength prediction**

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**Fig. S-1.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 50.

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**Fig. S-2.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 100.

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**Fig. S-3.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 150.

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**Fig. S-4.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 200.

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**Fig. S-5.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 250.

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**Fig. S-6.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 300.

**Table S-1** Performance of MFO-KNN models on the training set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.90 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
| 100 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.90 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
| 150 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.90 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
| 200 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.90 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
| 250 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | **0.90** | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
| 300 | 0.55 | 0.961 | 1 | 0.409 | 1 | 124.225 | 1 | 66.089 | 1 | 4 |
|  | 0.60 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.65 | 0.964 | 7 | 0.449 | 13 | 111.851 | 7 | 56.297 | 7 | 34 |
|  | 0.70 | 0.964 | 7 | 0.429 | 7 | 109.007 | 13 | 54.889 | 13 | 40 |
|  | 0.75 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.80 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.85 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |
|  | 0.90 | 1 | 19 | 1 | 19 | 0 | 19 | 0 | 19 | 76 |

**Table S-2** Performance of MFO-KNN models on the test set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | **0.80** | **0.975** | **31** | **0.4** | **31** | **116.123** | **43** | **71.406** | **43** | **148** |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |
| 100 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | 0.80 | 0.975 | 31 | 0.4 | 31 | 116.123 | 43 | 71.406 | 43 | 148 |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |
| 150 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | 0.80 | 0.975 | 31 | 0.4 | 31 | 116.123 | 43 | 71.406 | 43 | 148 |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |
| 200 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | 0.80 | 0.975 | 31 | 0.4 | 31 | 116.123 | 43 | 71.406 | 43 | 148 |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |
| 250 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | 0.80 | 0.975 | 31 | 0.4 | 31 | 116.123 | 43 | 71.406 | 43 | 148 |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |
| 300 | 0.55 | 0.497 | 25 | 0.382 | 13 | 486.503 | 25 | 169.096 | 25 | 88 |
|  | 0.60 | 0.442 | 7 | 0.327 | 1 | 536.962 | 19 | 207.631 | 7 | 34 |
|  | 0.65 | 0.479 | 19 | 0.488 | 43 | 544.918 | 13 | 186.255 | 19 | 94 |
|  | 0.70 | 0.464 | 13 | 0.459 | 37 | 585.725 | 7 | 208.285 | 1 | 58 |
|  | 0.75 | 0.401 | 1 | 0.387 | 25 | 608.958 | 1 | 206.018 | 13 | 40 |
|  | 0.80 | 0.975 | 31 | 0.4 | 31 | 116.123 | 43 | 71.406 | 43 | 148 |
|  | 0.85 | 0.977 | 43 | 0.368 | 7 | 126.071 | 37 | 76.793 | 37 | 124 |
|  | 0.90 | 0.976 | 37 | 0.385 | 19 | 147.399 | 31 | 92.589 | 31 | 118 |

**2. Results of failure modes identification**

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**Fig. S-7.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 50.

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A picture containing text, screenshot, colorfulness, graphic design

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**Fig. S-8.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 100.

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Description automatically generated

A picture containing screenshot, graphics, graphic design, colorfulness

Description automatically generated

**Fig. S-9.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 150.

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A picture containing screenshot, text, colorfulness, graphics

Description automatically generated

**Fig. S-10.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 200.

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A picture containing screenshot, graphics, colorfulness, graphic design

Description automatically generated

**Fig. S-11.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 250.

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A picture containing screenshot, colorfulness, graphics, text

Description automatically generated

**Fig. S-12.** Effect of training-test ratios on the MFO-KNN model’s performance with population size of 300.

**Table S-3** Performance of MFO-KNN models on the training set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 0.83 | 14 | 0.83 | 14 | 0.83 | 14 | 0.829 | 17 | 59 |
|  | 0.60 | 0.835 | 22 | 0.835 | 21 | 0.835 | 22 | 0.834 | 24 | 89 |
|  | 0.65 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.70 | 0.867 | 33 | 0.868 | 32 | 0.867 | 33 | 0.865 | 33 | 131 |
|  | 0.75 | 0.839 | 27 | 0.84 | 27 | 0.839 | 27 | 0.838 | 27 | 108 |
|  | **0.80** | 0.808 | 3 | 0.809 | 3 | 0.808 | 3 | 0.806 | 3 | 12 |
|  | 0.85 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.90 | 0.811 | 6 | 0.811 | 5 | 0.811 | 6 | 0.81 | 6 | 23 |
| 100 | 0.55 | 0.82 | 10 | 0.829 | 11 | 0.82 | 10 | 0.817 | 10 | 41 |
|  | 0.60 | 0.835 | 22 | 0.835 | 21 | 0.835 | 22 | 0.834 | 24 | 89 |
|  | 0.65 | 0.831 | 15 | 0.833 | 19 | 0.831 | 15 | 0.828 | 14 | 63 |
|  | 0.70 | 0.836 | 25 | 0.838 | 24 | 0.836 | 25 | 0.834 | 22 | 96 |
|  | 0.75 | 0.839 | 27 | 0.84 | 27 | 0.839 | 27 | 0.838 | 27 | 108 |
|  | 0.80 | 0.808 | 3 | 0.809 | 3 | 0.808 | 3 | 0.806 | 3 | 12 |
|  | 0.85 | 0.832 | 20 | 0.833 | 15 | 0.832 | 20 | 0.831 | 20 | 75 |
|  | 0.90 | 0.896 | 37 | 0.904 | 37 | 0.896 | 37 | 0.895 | 37 | 148 |
| 150 | 0.55 | 0.82 | 10 | 0.829 | 11 | 0.82 | 10 | 0.817 | 10 | 41 |
|  | 0.60 | 0.862 | 31 | 0.862 | 30 | 0.862 | 31 | 0.861 | 32 | 124 |
|  | 0.65 | 0.831 | 15 | 0.839 | 26 | 0.831 | 15 | 0.828 | 13 | 69 |
|  | 0.70 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.75 | 0.832 | 18 | 0.833 | 17 | 0.832 | 18 | 0.83 | 18 | 71 |
|  | 0.80 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.85 | 0.871 | 35 | 0.873 | 34 | 0.871 | 35 | 0.871 | 35 | 139 |
|  | 0.90 | 0.829 | 13 | 0.829 | 13 | 0.829 | 13 | 0.829 | 16 | 55 |
| 200 | 0.55 | 0.81 | 5 | 0.812 | 7 | 0.81 | 5 | 0.807 | 5 | 22 |
|  | 0.60 | 0.862 | 31 | 0.874 | 36 | 0.862 | 31 | 0.861 | 31 | 129 |
|  | 0.65 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.70 | 0.844 | 29 | 0.844 | 29 | 0.844 | 29 | 0.842 | 29 | 116 |
|  | 0.75 | 0.832 | 18 | 0.833 | 17 | 0.832 | 18 | 0.83 | 18 | 71 |
|  | 0.80 | 0.822 | 12 | 0.822 | 10 | 0.822 | 12 | 0.821 | 12 | 46 |
|  | 0.85 | 0.871 | 35 | 0.873 | 34 | 0.871 | 35 | 0.871 | 35 | 139 |
|  | 0.90 | 0.909 | 38 | 0.912 | 38 | 0.909 | 38 | 0.908 | 38 | 152 |
| 250 | 0.55 | 0.85 | 30 | 0.864 | 31 | 0.85 | 30 | 0.848 | 30 | 121 |
|  | 0.60 | 0.835 | 22 | 0.835 | 21 | 0.835 | 22 | 0.834 | 24 | 89 |
|  | 0.65 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.70 | 0.836 | 25 | 0.838 | 24 | 0.836 | 25 | 0.834 | 22 | 96 |
|  | 0.75 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.80 | 0.801 | 2 | 0.804 | 2 | 0.801 | 2 | 0.799 | 2 | 8 |
|  | 0.85 | 0.813 | 8 | 0.814 | 8 | 0.813 | 8 | 0.812 | 8 | 32 |
|  | 0.90 | 0.811 | 6 | 0.811 | 5 | 0.811 | 6 | 0.81 | 6 | 23 |
| 300 | 0.55 | 0.79 | 1 | 0.801 | 1 | 0.79 | 1 | 0.785 | 1 | 4 |
|  | 0.60 | 0.817 | 9 | 0.82 | 9 | 0.817 | 9 | 0.814 | 9 | 36 |
|  | 0.65 | 0.831 | 15 | 0.833 | 19 | 0.831 | 15 | 0.828 | 14 | 63 |
|  | 0.70 | 0.867 | 33 | 0.868 | 32 | 0.867 | 33 | 0.865 | 33 | 131 |
|  | 0.75 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.80 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |
|  | 0.85 | 0.832 | 20 | 0.833 | 15 | 0.832 | 20 | 0.831 | 20 | 75 |
|  | 0.90 | 1 | 39 | 1 | 39 | 1 | 39 | 1 | 39 | 156 |

**Table S-4** Performance of MFO-KNN models on the test set

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 0.711 | 28 | 0.709 | 29 | 0.711 | 28 | 0.709 | 30 | 115 |
|  | 0.60 | 0.716 | 31 | 0.723 | 30 | 0.716 | 31 | 0.718 | 31 | 123 |
|  | 0.65 | 0.754 | 40 | 0.759 | 40 | 0.754 | 40 | 0.754 | 40 | 160 |
|  | 0.70 | 0.691 | 24 | 0.693 | 23 | 0.691 | 24 | 0.691 | 24 | 95 |
|  | 0.75 | 0.609 | 11 | 0.623 | 13 | 0.609 | 11 | 0.608 | 12 | 47 |
|  | **0.80** | 0.622 | 15 | 0.646 | 19 | 0.622 | 15 | 0.625 | 15 | 64 |
|  | 0.85 | 0.75 | 39 | 0.748 | 39 | 0.75 | 39 | 0.748 | 39 | 156 |
|  | 0.90 | 0.579 | 7 | 0.621 | 11 | 0.579 | 7 | 0.576 | 5 | 30 |
| 100 | 0.55 | 0.723 | 34 | 0.726 | 33 | 0.723 | 34 | 0.718 | 34 | 135 |
|  | 0.60 | 0.716 | 31 | 0.723 | 30 | 0.716 | 31 | 0.718 | 31 | 123 |
|  | 0.65 | 0.646 | 19 | 0.643 | 17 | 0.646 | 19 | 0.643 | 19 | 74 |
|  | 0.70 | 0.636 | 17 | 0.639 | 15 | 0.636 | 17 | 0.635 | 17 | 66 |
|  | 0.75 | 0.587 | 9 | 0.605 | 6 | 0.587 | 9 | 0.586 | 9 | 33 |
|  | 0.80 | 0.622 | 15 | 0.646 | 19 | 0.622 | 15 | 0.625 | 15 | 64 |
|  | 0.85 | 0.571 | 5 | 0.598 | 4 | 0.571 | 5 | 0.577 | 7 | 21 |
|  | 0.90 | 0.684 | 23 | 0.707 | 27 | 0.684 | 23 | 0.682 | 23 | 96 |
| 150 | 0.55 | 0.723 | 34 | 0.726 | 33 | 0.723 | 34 | 0.718 | 34 | 135 |
|  | 0.60 | 0.743 | 38 | 0.746 | 38 | 0.743 | 38 | 0.744 | 38 | 152 |
|  | 0.65 | 0.677 | 22 | 0.684 | 22 | 0.677 | 22 | 0.673 | 22 | 88 |
|  | 0.70 | 0.782 | 44 | 0.787 | 45 | 0.782 | 44 | 0.777 | 44 | 177 |
|  | 0.75 | 0.609 | 11 | 0.616 | 8 | 0.609 | 11 | 0.607 | 10 | 40 |
|  | **0.80** | **0.784** | **46** | **0.788** | **46** | **0.784** | **46** | **0.779** | **45** | **183** |
|  | 0.85 | 0.536 | 2 | 0.546 | 2 | 0.536 | 2 | 0.522 | 2 | 8 |
|  | 0.90 | 0.526 | 1 | 0.542 | 1 | 0.526 | 1 | 0.513 | 1 | 4 |
| 200 | 0.55 | 0.711 | 28 | 0.709 | 28 | 0.711 | 28 | 0.708 | 29 | 113 |
|  | 0.60 | 0.73 | 36 | 0.737 | 36 | 0.73 | 36 | 0.73 | 36 | 144 |
|  | 0.65 | 0.754 | 40 | 0.759 | 40 | 0.754 | 40 | 0.754 | 40 | 160 |
|  | 0.70 | 0.618 | 14 | 0.62 | 10 | 0.618 | 14 | 0.617 | 14 | 52 |
|  | 0.75 | 0.609 | 11 | 0.616 | 8 | 0.609 | 11 | 0.607 | 10 | 40 |
|  | 0.80 | 0.649 | 21 | 0.655 | 21 | 0.649 | 21 | 0.649 | 21 | 84 |
|  | 0.85 | 0.536 | 2 | 0.546 | 2 | 0.536 | 2 | 0.522 | 2 | 8 |
|  | 0.90 | 0.737 | 37 | 0.741 | 37 | 0.737 | 37 | 0.734 | 37 | 148 |
| 250 | 0.55 | 0.699 | 26 | 0.704 | 26 | 0.699 | 26 | 0.691 | 26 | 104 |
|  | 0.60 | 0.716 | 31 | 0.723 | 30 | 0.716 | 31 | 0.718 | 31 | 123 |
|  | 0.65 | 0.754 | 40 | 0.759 | 40 | 0.754 | 40 | 0.754 | 40 | 160 |
|  | 0.70 | 0.636 | 17 | 0.639 | 15 | 0.636 | 17 | 0.635 | 17 | 66 |
|  | 0.75 | 0.783 | 45 | 0.785 | 44 | 0.783 | 45 | 0.78 | 47 | 181 |
|  | 0.80 | 0.568 | 4 | 0.606 | 7 | 0.568 | 4 | 0.569 | 4 | 19 |
|  | 0.85 | 0.607 | 10 | 0.625 | 14 | 0.607 | 10 | 0.611 | 13 | 47 |
|  | 0.90 | 0.579 | 7 | 0.621 | 11 | 0.579 | 7 | 0.576 | 5 | 30 |
| 300 | 0.55 | 0.711 | 28 | 0.728 | 35 | 0.711 | 28 | 0.705 | 28 | 119 |
|  | 0.60 | 0.703 | 27 | 0.701 | 25 | 0.703 | 27 | 0.701 | 27 | 106 |
|  | 0.65 | 0.646 | 19 | 0.643 | 17 | 0.646 | 19 | 0.643 | 19 | 74 |
|  | 0.70 | 0.691 | 24 | 0.693 | 23 | 0.691 | 24 | 0.691 | 24 | 95 |
|  | 0.75 | 0.761 | 43 | 0.768 | 43 | 0.761 | 43 | 0.761 | 43 | 172 |
|  | 0.80 | 0.784 | 46 | 0.788 | 46 | 0.784 | 46 | 0.779 | 45 | 183 |
|  | 0.85 | 0.571 | 5 | 0.598 | 4 | 0.571 | 5 | 0.577 | 7 | 21 |
|  | 0.90 | 0.789 | 48 | 0.799 | 48 | 0.789 | 48 | 0.789 | 48 | 192 |

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Description automatically generated with low confidence

**Fig. S-13.** Performance of MFO-KNN models.