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

Viet-Linh Tran1, Duy-Duan Nguyen1, Van-Tien Phan1, Trong-Ha Nguyen1, Tae-Hyung Lee2\*

1 Department of Civil Engineering, Vinh University, Vinh 461010, Vietnam

2 Department of Civil and Environmental Engineering, Konkuk University, Seoul 05029, Korea

\*Corresponding author

Email addresses: vietlinh.dhv@gmail.com (Viet-Linh Tran); duan468@gmail.com (Duy-Duan Nguyen); vantienkxd@vinhuni.edu.vn (Van-Tien Phan); trongha.kxd@gmail.com (Trong-Ha Nguyen); thlee@konkuk.ac.kr (Tae-Hyung Lee)

**1. Results of shear strength prediction**

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

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

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

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

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

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**Fig. S-5.** Effect of training-test ratios on the MFO-XGB model’s performance with population size of 300.

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

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | 1 | 25 | 0.879 | 17 | 12.601 | 27 | 8.159 | 26 | 95 |
|  | 0.60 | 0.999 | 12 | 0.889 | 20 | 13.685 | 24 | 9.008 | 24 | 80 |
|  | 0.65 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.70 | 0.998 | 7 | 0.714 | 7 | 25.921 | 9 | 20.246 | 7 | 30 |
|  | 0.75 | 0.997 | 1 | 0.656 | 4 | 31.511 | 5 | 23.128 | 4 | 14 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.069 | 32 | 0.018 | 32 | 119 |
|  | 0.85 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.90 | 1 | 25 | 1 | 30 | 0.02 | 33 | 0.01 | 33 | 121 |
| 100 | 0.55 | 1 | 25 | 0.909 | 25 | 12.383 | 28 | 7.563 | 27 | 105 |
|  | 0.60 | 0.999 | 12 | 0.889 | 20 | 13.855 | 22 | 9.077 | 23 | 77 |
|  | 0.65 | 0.999 | 12 | 0.859 | 14 | 16.623 | 18 | 12.236 | 15 | 59 |
|  | 0.70 | 0.997 | 1 | 0.655 | 3 | 30.121 | 6 | 23.729 | 3 | 13 |
|  | 0.75 | 0.998 | 7 | 0.722 | 8 | 23.382 | 11 | 18.156 | 8 | 34 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.85 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.90 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
| 150 | 0.55 | 1 | 25 | 0.924 | 26 | 11.165 | 29 | 6.875 | 28 | 108 |
|  | 0.60 | 0.999 | 12 | 0.889 | 20 | 13.814 | 23 | 9.199 | 21 | 76 |
|  | 0.65 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.70 | 0.998 | 7 | 0.679 | 5 | 26.608 | 8 | 20.576 | 6 | 26 |
|  | 0.75 | 0.999 | 12 | 0.789 | 12 | 18.983 | 14 | 14.846 | 12 | 50 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.85 | 1 | 25 | 1 | 30 | 0.002 | 37 | 0.001 | 37 | 129 |
|  | 0.90 | 0.997 | 1 | 0.944 | 28 | 33.6 | 2 | 9.391 | 20 | 51 |
| 200 | 0.55 | 1 | 25 | 0.879 | 17 | 13.339 | 26 | 8.901 | 25 | 93 |
|  | 0.60 | 0.999 | 12 | 0.875 | 16 | 15.131 | 19 | 10.278 | 17 | 64 |
|  | 0.65 | 0.998 | 7 | 0.782 | 10 | 23.396 | 10 | 17.684 | 9 | 36 |
|  | 0.70 | 0.998 | 7 | 0.702 | 6 | 27.484 | 7 | 21.472 | 5 | 25 |
|  | 0.75 | 0.997 | 1 | 0.622 | 2 | 32.802 | 4 | 24.054 | 2 | 9 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.006 | 34 | 0.003 | 34 | 123 |
|  | 0.85 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.90 | 1 | 25 | 1 | 30 | 0.005 | 35 | 0.002 | 35 | 125 |
| 250 | 0.55 | 1 | 25 | 0.879 | 17 | 13.647 | 25 | 9.131 | 22 | 89 |
|  | 0.60 | 0.999 | 12 | 0.889 | 20 | 13.979 | 21 | 9.461 | 19 | 72 |
|  | 0.65 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.70 | 0.997 | 1 | 0.619 | 1 | 32.888 | 3 | 25.466 | 1 | 6 |
|  | 0.75 | 0.999 | 12 | 0.756 | 9 | 21.795 | 12 | 17.237 | 10 | 43 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | 0.85 | 1 | 25 | 1 | 30 | 0.001 | 38 | 0.001 | 37 | 130 |
|  | **0.90** | 0.997 | 1 | 0.944 | 28 | 35.186 | 1 | 10.514 | 16 | 46 |
| 300 | 0.55 | 1 | 25 | 0.924 | 26 | 10.865 | 30 | 6.638 | 29 | 110 |
|  | 0.60 | 0.999 | 12 | 0.889 | 20 | 14.33 | 20 | 9.601 | 18 | 70 |
|  | 0.65 | 0.999 | 12 | 0.859 | 14 | 18.161 | 15 | 13.575 | 14 | 55 |
|  | 0.70 | 0.999 | 12 | 0.786 | 11 | 19.913 | 13 | 15.683 | 11 | 47 |
|  | 0.75 | 0.999 | 12 | 0.789 | 12 | 17.952 | 16 | 14.071 | 13 | 53 |
|  | 0.80 | 1 | 25 | 1 | 30 | 0.167 | 31 | 0.102 | 31 | 117 |
|  | 0.85 | 0.999 | 12 | 1 | 30 | 16.662 | 17 | 5.615 | 30 | 89 |
|  | 0.90 | 1 | 25 | 1 | 30 | 0.003 | 36 | 0.002 | 35 | 126 |

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

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **R2** | **Score** | **A10** | **Score** | **RMSE** | **Score** | **MAE** | **Score** | **Total** |
| 50 | 0.55 | 0.465 | 28 | 0.2 | 1 | 501.61 | 28 | 187.791 | 28 | 85 |
|  | 0.60 | 0.457 | 20 | 0.224 | 8 | 529.566 | 20 | 192.623 | 21 | 69 |
|  | 0.65 | 0.423 | 15 | 0.395 | 32 | 573.361 | 16 | 210.72 | 13 | 76 |
|  | 0.70 | 0.416 | 13 | 0.27 | 15 | 611.106 | 9 | 219.57 | 3 | 40 |
|  | 0.75 | 0.403 | 7 | 0.29 | 16 | 607.792 | 11 | 212.53 | 11 | 45 |
|  | 0.80 | 0.945 | 32 | 0.48 | 43 | 171.082 | 36 | 82.22 | 38 | 149 |
|  | 0.85 | 0.943 | 31 | 0.421 | 37 | 196.518 | 31 | 98.229 | 31 | 130 |
|  | 0.90 | 0.979 | 40 | 0.385 | 29 | 137.126 | 39 | 92.256 | 33 | 141 |
| 100 | 0.55 | 0.468 | 30 | 0.218 | 4 | 500.348 | 30 | 188.217 | 27 | 91 |
|  | 0.60 | 0.458 | 22 | 0.245 | 12 | 529.094 | 22 | 192.809 | 20 | 76 |
|  | 0.65 | 0.411 | 12 | 0.349 | 24 | 579.47 | 15 | 197.599 | 18 | 69 |
|  | 0.70 | 0.419 | 14 | 0.297 | 17 | 609.354 | 10 | 221.196 | 2 | 43 |
|  | 0.75 | 0.395 | 4 | 0.323 | 21 | 611.906 | 7 | 212.994 | 9 | 41 |
|  | 0.80 | 0.979 | 40 | 0.56 | 45 | 105.749 | 44 | 63.287 | 46 | 175 |
|  | 0.85 | 0.951 | 34 | 0.474 | 41 | 182.571 | 32 | 90.956 | 35 | 142 |
|  | 0.90 | 0.983 | 44 | 0.538 | 44 | 124.465 | 41 | 73.389 | 41 | 170 |
| 150 | 0.55 | 0.462 | 26 | 0.218 | 4 | 502.847 | 26 | 189.723 | 25 | 81 |
|  | 0.60 | 0.458 | 22 | 0.245 | 12 | 529.029 | 23 | 192.832 | 19 | 76 |
|  | 0.65 | 0.424 | 16 | 0.395 | 32 | 573.029 | 17 | 209.341 | 14 | 79 |
|  | 0.70 | 0.398 | 6 | 0.297 | 17 | 620.342 | 1 | 217.984 | 5 | 29 |
|  | 0.75 | 0.393 | 3 | 0.355 | 26 | 612.837 | 6 | 215.848 | 7 | 42 |
|  | 0.80 | 0.979 | 40 | 0.56 | 45 | 105.823 | 42 | 63.379 | 44 | 171 |
|  | 0.85 | 0.951 | 34 | 0.421 | 37 | 182.29 | 33 | 92.185 | 34 | 138 |
|  | 0.90 | 0.995 | 47 | 0.308 | 19 | 69.255 | 47 | 59.598 | 47 | 160 |
| 200 | 0.55 | 0.46 | 24 | 0.218 | 4 | 504.193 | 25 | 180.34 | 30 | 83 |
|  | 0.60 | 0.461 | 25 | 0.245 | 12 | 527.718 | 24 | 192.57 | 22 | 83 |
|  | 0.65 | 0.41 | 11 | 0.326 | 23 | 579.752 | 14 | 198.356 | 16 | 64 |
|  | 0.70 | 0.408 | 9 | 0.243 | 11 | 615.525 | 4 | 219.237 | 4 | 28 |
|  | 0.75 | 0.397 | 5 | 0.387 | 31 | 611.169 | 8 | 212.794 | 10 | 54 |
|  | 0.80 | 0.949 | 33 | 0.4 | 35 | 164.768 | 38 | 79.099 | 39 | 145 |
|  | 0.85 | 0.952 | 36 | 0.316 | 20 | 181.119 | 34 | 96.207 | 32 | 122 |
|  | 0.90 | 0.99 | 45 | 0.462 | 40 | 95.139 | 45 | 68.982 | 43 | 173 |
| 250 | 0.55 | 0.467 | 29 | 0.218 | 4 | 500.715 | 29 | 187.026 | 29 | 91 |
|  | 0.60 | 0.444 | 19 | 0.224 | 8 | 535.943 | 19 | 192.524 | 23 | 69 |
|  | 0.65 | 0.424 | 16 | 0.395 | 32 | 573.024 | 18 | 209.325 | 15 | 81 |
|  | 0.70 | 0.407 | 8 | 0.216 | 3 | 616.016 | 3 | 223.304 | 1 | 15 |
|  | 0.75 | 0.387 | 1 | 0.323 | 21 | 616.087 | 2 | 215.233 | 8 | 32 |
|  | 0.80 | 0.979 | 40 | 0.56 | 45 | 105.822 | 43 | 63.35 | 45 | 173 |
|  | 0.85 | 0.953 | 37 | 0.421 | 37 | 178.043 | 35 | 88.489 | 36 | 145 |
|  | **0.90** | **0.996** | **48** | **0.615** | **48** | **62.427** | **48** | **46.027** | **48** | **192** |
| 300 | 0.55 | 0.463 | 27 | 0.2 | 1 | 502.624 | 27 | 188.253 | 26 | 81 |
|  | 0.60 | 0.457 | 20 | 0.224 | 8 | 529.508 | 21 | 192.363 | 24 | 73 |
|  | 0.65 | 0.409 | 10 | 0.349 | 24 | 580.328 | 13 | 197.648 | 17 | 64 |
|  | 0.70 | 0.431 | 18 | 0.405 | 36 | 603.333 | 12 | 211.166 | 12 | 78 |
|  | 0.75 | 0.391 | 2 | 0.355 | 26 | 614.075 | 5 | 216.622 | 6 | 39 |
|  | 0.80 | 0.967 | 39 | 0.36 | 28 | 133.606 | 40 | 71.983 | 42 | 149 |
|  | 0.85 | 0.959 | 38 | 0.474 | 41 | 166.352 | 37 | 86.436 | 37 | 153 |
|  | 0.90 | 0.99 | 45 | 0.385 | 29 | 94.243 | 46 | 74.671 | 40 | 160 |

**2. Results of failure modes identification**

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

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

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A picture containing screenshot, colorfulness, graphics, magenta

Description automatically generated

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

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A picture containing screenshot, colorfulness, graphics, magenta

Description automatically generated

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

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A picture containing screenshot, colorfulness, graphics, magenta

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

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

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

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | **0.85** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **1** | **4** |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 100 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 150 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 200 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 250 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
| 300 | 0.55 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.60 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |
|  | 0.90 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 4 |

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

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Pop** | **Tr.atio** | **Acc** | **Score** | **Pre** | **Score** | **Re** | **Score** | **f1** | **Score** | **Total** |
| 50 | 0.55 | 0.88 | 21 | 0.884 | 22 | 0.88 | 21 | 0.879 | 22 | 86 |
|  | 0.60 | 0.851 | 2 | 0.856 | 4 | 0.851 | 2 | 0.851 | 5 | 13 |
|  | 0.65 | 0.877 | 16 | 0.88 | 18 | 0.877 | 16 | 0.877 | 17 | 67 |
|  | 0.70 | 0.873 | 12 | 0.875 | 11 | 0.873 | 12 | 0.872 | 12 | 47 |
|  | 0.75 | 0.913 | 38 | 0.913 | 38 | 0.913 | 38 | 0.913 | 39 | 153 |
|  | 0.80 | 0.892 | 26 | 0.895 | 32 | 0.892 | 26 | 0.891 | 25 | 109 |
|  | **0.85** | **0.929** | **43** | **0.929** | **43** | **0.929** | **43** | **0.929** | **43** | **172** |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |
| 100 | 0.55 | 0.867 | 9 | 0.877 | 15 | 0.867 | 9 | 0.866 | 11 | 44 |
|  | 0.60 | 0.851 | 2 | 0.851 | 2 | 0.851 | 2 | 0.85 | 2 | 8 |
|  | 0.65 | 0.877 | 16 | 0.88 | 18 | 0.877 | 16 | 0.877 | 17 | 67 |
|  | 0.70 | 0.873 | 12 | 0.875 | 11 | 0.873 | 12 | 0.872 | 12 | 47 |
|  | 0.75 | 0.913 | 38 | 0.913 | 38 | 0.913 | 38 | 0.913 | 39 | 153 |
|  | 0.80 | 0.892 | 26 | 0.905 | 34 | 0.892 | 26 | 0.892 | 28 | 114 |
|  | 0.85 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 172 |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |
| 150 | 0.55 | 0.867 | 9 | 0.867 | 8 | 0.867 | 9 | 0.866 | 9 | 35 |
|  | 0.60 | 0.851 | 2 | 0.856 | 4 | 0.851 | 2 | 0.851 | 5 | 13 |
|  | 0.65 | 0.862 | 8 | 0.865 | 7 | 0.862 | 8 | 0.861 | 8 | 31 |
|  | 0.70 | 0.873 | 12 | 0.875 | 11 | 0.873 | 12 | 0.872 | 12 | 47 |
|  | 0.75 | 0.891 | 25 | 0.891 | 23 | 0.891 | 25 | 0.89 | 24 | 97 |
|  | 0.80 | 0.892 | 26 | 0.905 | 34 | 0.892 | 26 | 0.892 | 28 | 114 |
|  | 0.85 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 172 |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |
| 200 | 0.55 | 0.867 | 9 | 0.867 | 8 | 0.867 | 9 | 0.866 | 9 | 35 |
|  | 0.60 | 0.838 | 1 | 0.844 | 1 | 0.838 | 1 | 0.838 | 1 | 4 |
|  | 0.65 | 0.877 | 16 | 0.88 | 18 | 0.877 | 16 | 0.877 | 17 | 67 |
|  | 0.70 | 0.873 | 12 | 0.875 | 11 | 0.873 | 12 | 0.872 | 12 | 47 |
|  | 0.75 | 0.913 | 38 | 0.914 | 42 | 0.913 | 38 | 0.913 | 38 | 156 |
|  | 0.80 | 0.892 | 26 | 0.895 | 32 | 0.892 | 26 | 0.891 | 25 | 109 |
|  | 0.85 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 172 |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |
| 250 | 0.55 | 0.88 | 21 | 0.88 | 17 | 0.88 | 21 | 0.878 | 21 | 80 |
|  | 0.60 | 0.851 | 2 | 0.851 | 2 | 0.851 | 2 | 0.85 | 2 | 8 |
|  | 0.65 | 0.877 | 16 | 0.88 | 18 | 0.877 | 16 | 0.877 | 17 | 67 |
|  | 0.70 | 0.891 | 23 | 0.895 | 31 | 0.891 | 23 | 0.891 | 27 | 104 |
|  | 0.75 | 0.913 | 38 | 0.913 | 38 | 0.913 | 38 | 0.913 | 39 | 153 |
|  | 0.80 | 0.892 | 26 | 0.905 | 34 | 0.892 | 26 | 0.892 | 28 | 114 |
|  | 0.85 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 172 |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |
| 300 | 0.55 | 0.855 | 7 | 0.869 | 10 | 0.855 | 7 | 0.855 | 7 | 31 |
|  | 0.60 | 0.851 | 2 | 0.858 | 6 | 0.851 | 2 | 0.85 | 4 | 14 |
|  | 0.65 | 0.877 | 16 | 0.879 | 16 | 0.877 | 16 | 0.876 | 16 | 64 |
|  | 0.70 | 0.891 | 23 | 0.892 | 24 | 0.891 | 23 | 0.89 | 23 | 93 |
|  | 0.75 | 0.913 | 38 | 0.913 | 38 | 0.913 | 38 | 0.913 | 39 | 153 |
|  | 0.80 | 0.892 | 26 | 0.905 | 34 | 0.892 | 26 | 0.892 | 28 | 114 |
|  | 0.85 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 0.929 | 43 | 172 |
|  | 0.90 | 0.895 | 32 | 0.895 | 25 | 0.895 | 32 | 0.895 | 32 | 121 |

A blue and white squares with numbers

Description automatically generated with low confidenceA screenshot of a computer

Description automatically generated with low confidence

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