Supplementary Material

**Table S1.** Performance difference between the pooled model (generalized model) and the non-pooled model (site-specific model, which is used in this study). The "generalized model" was developed using data from three regions and tested on the remaining region (Florida Panhandle from Hurricane Michael), which was not used in the training process. The "site-specific model" was developed using data from the Florida Panhandle affected by Hurricane Michael. Both models were evaluated using 5-fold cross-validation. For the "generalized model", we observed relatively low model performance for 9 out of the 11 structural features, excluding the wall structure and roof system (with an average difference of 0.12 in the F1-score and 0.22 in R2 value). This finding indicates that the four regions have different constructional trends, making it difficult to create a global model with maximized generalization across all regions. Therefore, we developed site-specific models without pooling all the reconnaissance data.

|  |  |  |  |
| --- | --- | --- | --- |
| **Structural feature** | **Generalized model** | **Site-specific model** | **Performance differences** |
| Number of stories | 0.62 | 0.75 | 0.13 |
| Primary roof shape | 0.52 | 0.67 | 0.15 |
| Secondary roof shape | 0.87 | 0.91 | 0.04 |
| Wall structure | 0.96 | 0.95 | -0.01 |
| Primary wall cladding | 0.47 | 0.65 | 0.18 |
| Secondary wall cladding | 0.61 | 0.81 | 0.20 |
| Large door present | 0.72 | 0.81 | 0.09 |
| Roof system | NaN | NaN | NaN |
| Roof cover | 0.72 | 0.74 | 0.02 |
| Building age | 0.42 | 0.68 | 0.26 |
| First-floor elevation | 0.22 | 0.41 | 0.19 |

**Table S2.** Performance difference between the 5-fold cross-validation and 3-fold cross-validation. The difference was calculated by subtracting the results of the 5-fold cross-validation from those of the 3-fold cross-validation. We listed the region and hurricane name in order. GT is Galveston, Texas, FPK is Florida Peninsula and Keys, FP is Florida Panhandle, and SL is Southwest Louisiana.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Structural feature** | **GT, Harvey** | **FPK, Irma** | **FP, Michael** | **SL, Laura** |
| Number of stories | 0.01 | -0.01 | 0.02 | -0.02 |
| Primary roof shape | -0.02 | -0.02 | 0.01 | 0.00 |
| Secondary roof shape | -0.01 | -0.01 | -0.02 | 0.00 |
| Wall structure | 0.00 | 0.00 | 0.01 | NaN |
| Primary wall cladding | 0.01 | -0.01 | -0.01 | 0.01 |
| Secondary wall cladding | 0.00 | 0.01 | -0.03 | 0.01 |
| Large door present | -0.02 | 0.01 | 0.00 | 0.01 |
| Roof system | 0.00 | 0.00 | NaN | NaN |
| Roof cover | 0.00 | 0.00 | -0.02 | -0.01 |
| Building age | 0.05 | -0.01 | -0.06 | -0.09 |
| First-floor elevation | 0.00 | -0.02 | -0.02 | 0.00 |

**Table S3.** Performance difference between the 5-fold cross-validation and 10-fold cross-validation. The difference was calculated by subtracting the results of the 5-fold cross-validation from those of the 10-fold cross-validation. We listed the region and hurricane name in order. GT is Galveston, Texas, FPK is Florida Peninsula and Keys, FP is Florida Panhandle, and SL is Southwest Louisiana.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Structural feature** | **GT, Harvey** | **FPK, Irma** | **FP, Michael** | **SL, Laura** |
| Number of stories | 0.01 | 0.01 | 0.02 | -0.01 |
| Primary roof shape | -0.02 | 0.00 | 0.01 | -0.01 |
| Secondary roof shape | 0.00 | -0.01 | -0.01 | 0.01 |
| Wall structure | 0.00 | 0.00 | 0.00 | NaN |
| Primary wall cladding | 0.01 | -0.01 | 0.01 | 0.00 |
| Secondary wall cladding | 0.00 | 0.01 | -0.01 | 0.00 |
| Large door present | -0.01 | 0.01 | 0.01 | 0.01 |
| Roof system | 0.00 | 0.00 | NaN | NaN |
| Roof cover | 0.00 | -0.03 | -0.01 | -0.00 |
| Building age | 0.02 | 0.02 | -0.02 | -0.02 |
| First-floor elevation | 0.00 | 0.01 | 0.01 | 0.00 |

**Table S4.** Performance difference between the XGBoost model trained with the full dataset and the XGBoost model trained without the fully destroyed cases (a positive value indicates that the XGBoost model trained with the full dataset performed better). We listed the region and hurricane name in order. GT is Galveston, Texas, FPK is Florida Peninsula and Keys, FP is Florida Panhandle, and SL is Southwest Louisiana.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Structural feature** | **GT, Harvey** | **FPK, Irma** | **FP, Michael** | **SL, Laura** |
| Number of stories | 0.00 | 0.01 | -0.01 | -0.01 |
| Primary roof shape | 0.01 | 0.02 | 0.00 | 0.01 |
| Secondary roof shape | -0.01 | 0.00 | 0.03 | -0.01 |
| Wall structure | 0.00 | 0.00 | 0.00 | NaN |
| Primary wall cladding | 0.00 | 0.03 | 0.00 | -0.01 |
| Secondary wall cladding | 0.00 | 0.01 | 0.00 | 0.01 |
| Large door present | 0.00 | 0.01 | -0.01 | 0.01 |
| Roof system | 0.00 | 0.01 | NaN | NaN |
| Roof cover | 0.00 | 0.00 | 0.01 | 0.00 |
| Building age | 0.01 | 0.02 | 0.05 | 0.04 |
| First-floor elevation | 0.00 | 0.04 | 0.00 | 0.02 |



**Figure S1.** Confusion matrix for the number of stories of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S2.** Confusion matrix for the primary roof shape of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S3.** Confusion matrix for secondary roof shape of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S4.** Confusion matrix for wall structure of buildings affected by Hurricane (a) Harvey, (b) Irma, and (c) Michael based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S5.** Confusion matrix for primary wall cladding of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S6.** Confusion matrix for secondary wall cladding of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S7.** Confusion matrix for large door present of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S8.** Confusion matrix for roof system of buildings affected by Hurricane (a) Harvey and (b) Irma based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S9.** Confusion matrix for roof cover of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. Each cell in the matrix presents two values: the upper value represents the percentage of data points classified into that cell relative to the total number of each observed category. The value inside the parentheses indicates the actual number of data points corresponding to that percentage.



**Figure S10.** Scatter plot for age of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. The solid line represents the 1:1 line.



**Figure S11.** Scatter plot for first-floor elevation of buildings affected by Hurricane (a) Harvey, (b) Irma, (c) Michael, and (d) Laura based on developed XGBoost models. The solid line represents the 1:1 line.



**Figure S12.** Distribution of the number of stories of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S13.** Distribution of primary roof shape of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S14.** Distribution of secondary roof shape of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S15.** Distribution of wall structure of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, and (c) Florida Panhandle affected by Hurricane Michael.



**Figure S16.** Distribution of primary wall cladding of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S17.** Distribution of secondary wall cladding of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S18.** Distribution of large door present of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S19.** Distribution of roof system of buildings in (a) Galveston, Texas affected by Hurricane Harvey and (b) Florida Peninsula and Keys affected by Hurricane Irma.



**Figure S20.** Distribution of roof cover of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S21.** Distribution of age of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S22.** Distribution of first-floor elevation of buildings in (a) Galveston, Texas affected by Hurricane Harvey, (b) Florida Peninsula and Keys affected by Hurricane Irma, (c) Florida Panhandle affected by Hurricane Michael, and (d) Southwest Louisiana affected by Hurricane Laura.



**Figure S23.** SHAP waterfall plots illustrating the prediction process of XGBoost models for five roof system classes ((a) Brick/Masonry, (b) Concrete/Wood, (c) Masonry/Concrete, (d) Wood, and (e) Wood/Masonry).