MSc Graduation Presentation on:

Enhancing Building Facade Resilience Analysis through Machine Learning

Improving Workflow for Seismic and Heat Wave Resilience Measures

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Delft University of Technology

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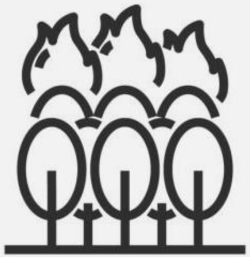
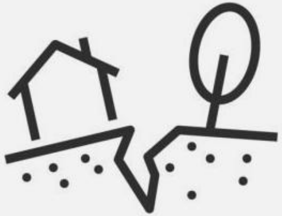
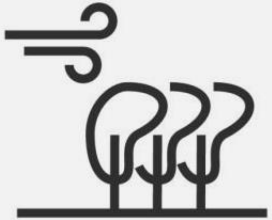
Sheet count : 78
Time : 25 - 30 minutes

Problem Statement

Our planet faces significant challenges due to drastic climatic change, resulting in catastrophic events!

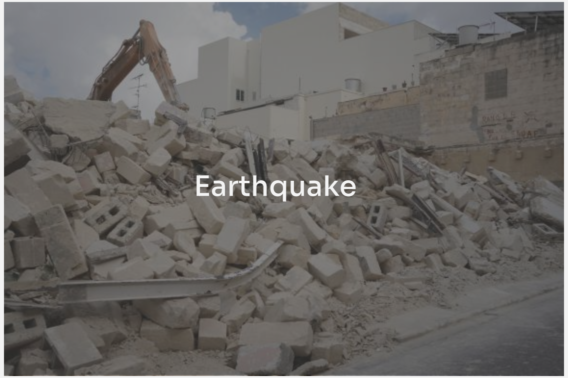






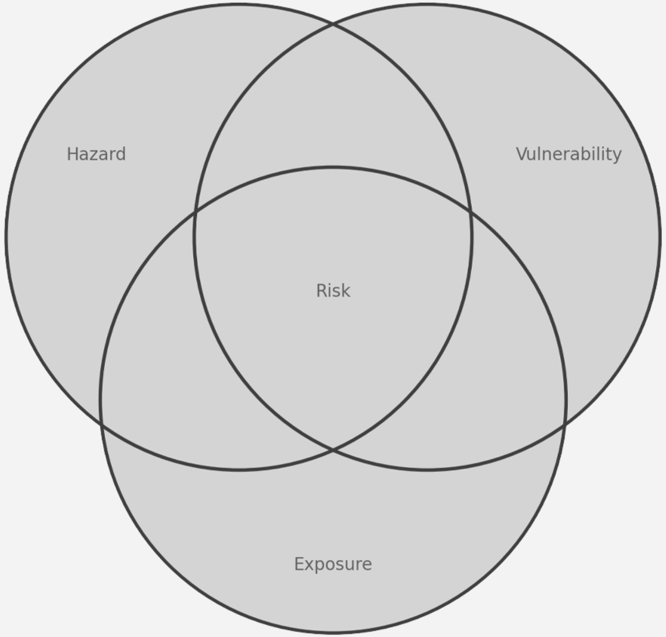
Building Vulnerability

Multiple Hazards



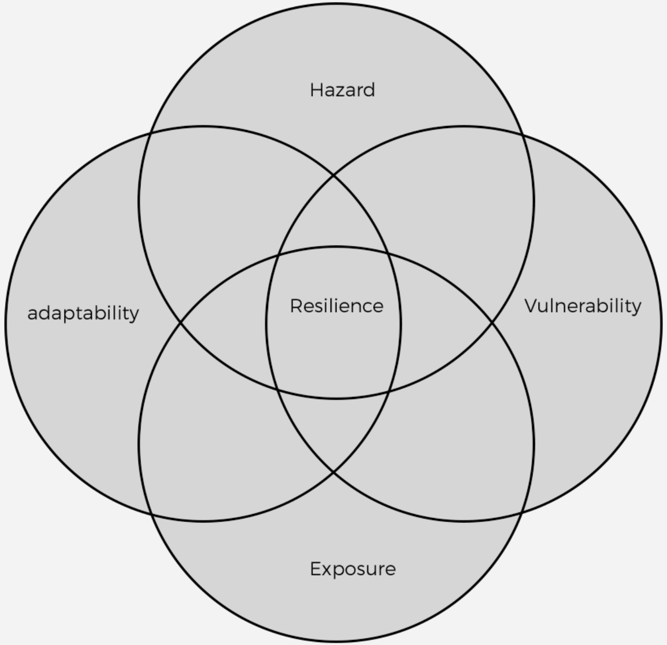
Risk to Humans

Risk to Humans



Risk to the buildings is a function of the hazard, vulnerability to the hazard and its exposure to the hazard

Resilience



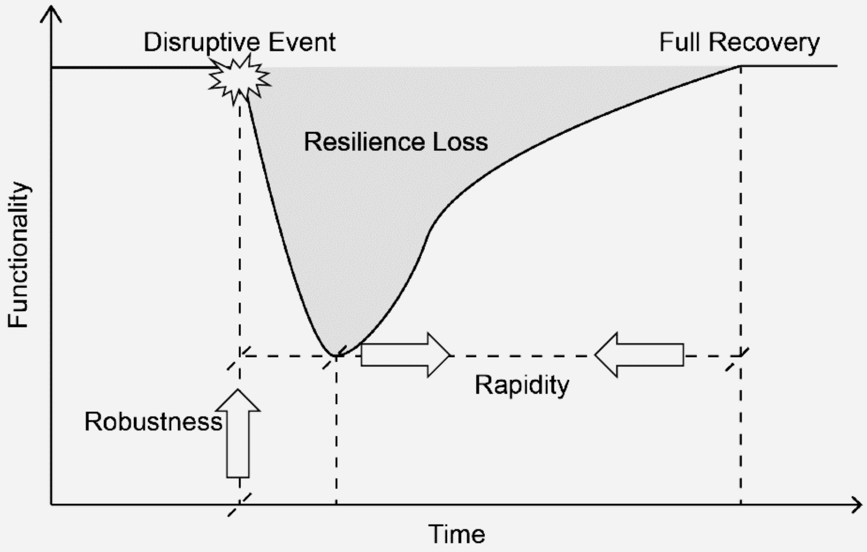
Resilience can help adapt to the risks on the building facade

What is Resilience?

The American Psychological Association (2014) defines resilience as "the process of adapting well in the face of adversity, trauma, tragedy, threats or even significant sources of stress"

State of Art

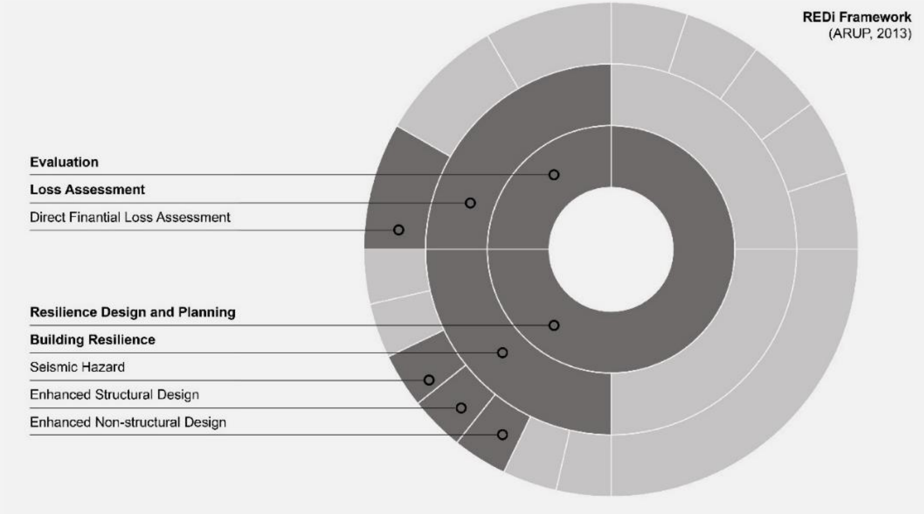
Resilience-based design approach aims for minimizing disruption impact and facilitating prompt recovery to operational status

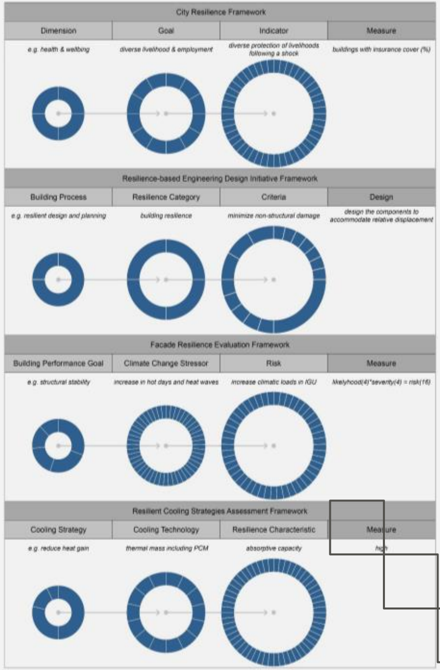


Source - Kim, K. (2023). Resilience-based Facade Design Framework.

State of Art

Resilience-based design frameworks are limited, primarily using qualitative assessment and relying on expert evaluations





Why Building Facades?

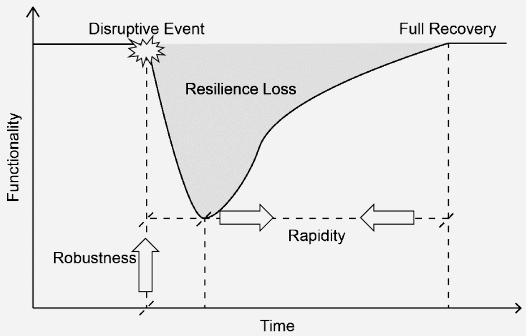
Situated at the interface between a building's exterior and interior, the facade fulfills a myriad of complex roles encompassing environmental, structural, and operational performance.

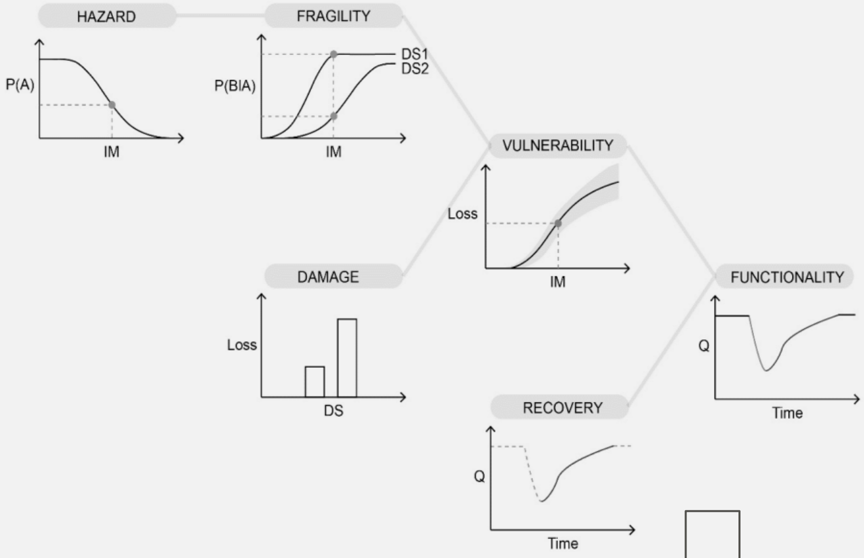
75% of buildings were susceptible to damage in non-structural Elements

1994 Northridge Earhtquake (Charleson, 2008)

State of Art

Resilience-based design approach aims for minimizing disruption impact and facilitating prompt recovery to operational status

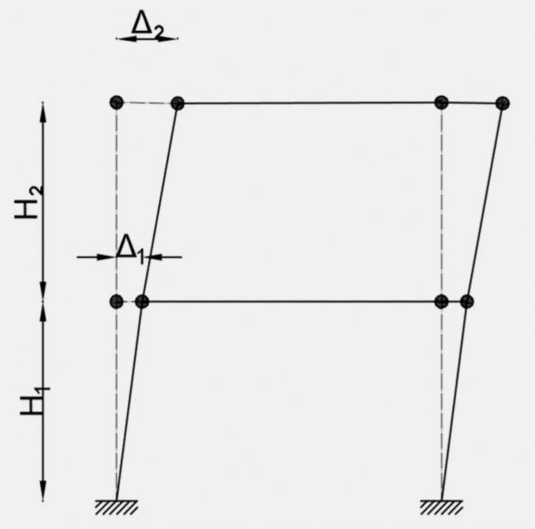




Source - Kim, K. (2023). Resilience-based Facade Design Framework.

State of Art

Seismic Resilience metric – Inter- story Drift angle



State of Art

Thermal Resilience metrics as design criteria for building facades

Literature	Application Scenario	Resilience Metrics
Kesik et al., 2019	Power outage due to extreme weather	Thermal autonomy, Passive Habitability
Katal et al., 2019	Power outage due to historical snowstorm	Passive Survivability
O'Brien & Bennet, 2016	Power failure during winter and summer	Passive Survivability, Thermal Autonomy
Ozkan et al., 2019	Power outage during extreme weather	Passive Survivability, Thermal Autonomy
White & Wright, 2020	Power outage during resilience design week	Passive Survivability
Homaei & Hamdy, 2021a	Power outage during coldest and warmest periods	Active Survivability
Baniassadi & Sailor, 2018	Power outage during extreme heat episodes	Discomfort Index
Sailor, 2014	Global/local warming, Power outage, Failed AC operations	Predicted Percent Dissatisfied
Mathew et al., 2021	Power outage with 5 outdoor temperature conditions	Occupant Hours Lost Degree Hours
Hamdy et al., 2017	Historical and future climate scenario, Ventilative cooling	Indoor Overheating Degree
Ji et al., 2023	Heatwave during summertime, Natural ventilation	Thermal Resilience Index
Homaei & Hamdy, 2021b	Power failure during 5 days	Weighted Unmet Thermal Performance

Thermal Resilience metrics in Literature

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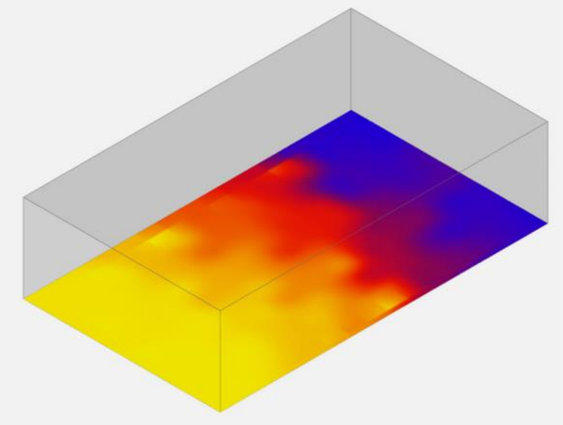
Thermal Resilience metric – Spatial Thermal Autonomy



$$\frac{\textit{Degree hours below comfort threshold}}{\textit{Total hours in the analysis period}}$$

Thermal Resilience metrics in Literature

State of Art

- What is Resilience?
- Need for Quantitative Resilience design framework
- Seismic Resilience Metric as Inter-story Drift angles
- Thermal Resilience metric as Spatial thermal Autonomy

Thermal Resilience metrics in Literature

Resilience-based

Façade Design Framework

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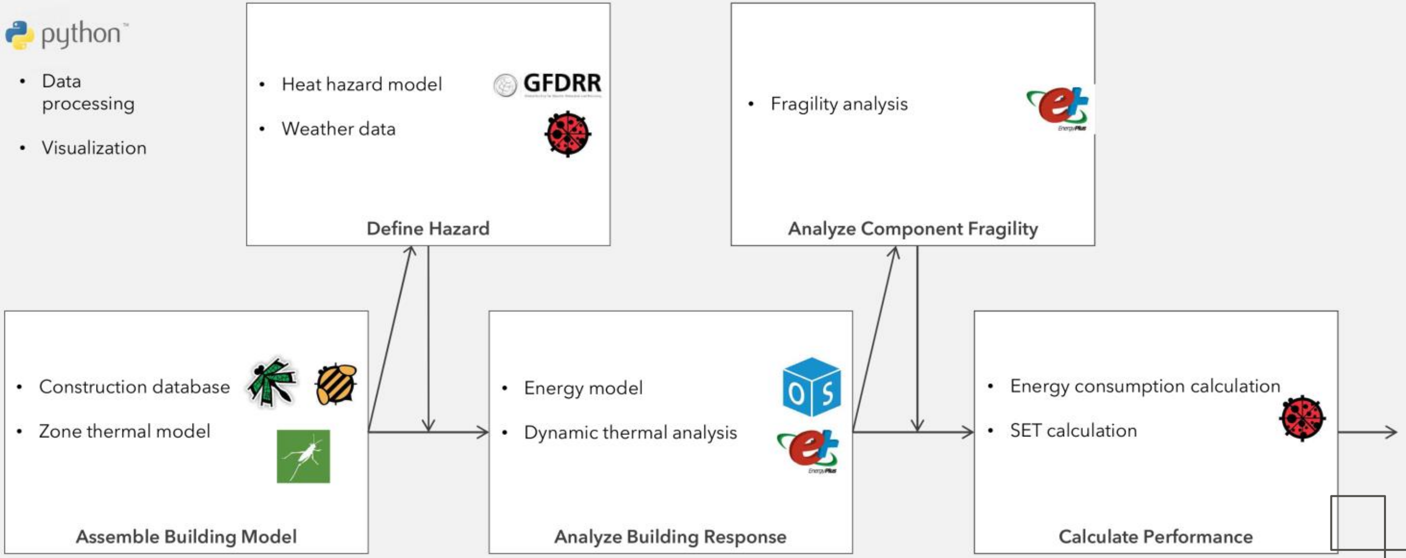
How to Quantify Thermal Resilience?



Source - Kim, K. (2023). Resilience-based Facade Design Framework.

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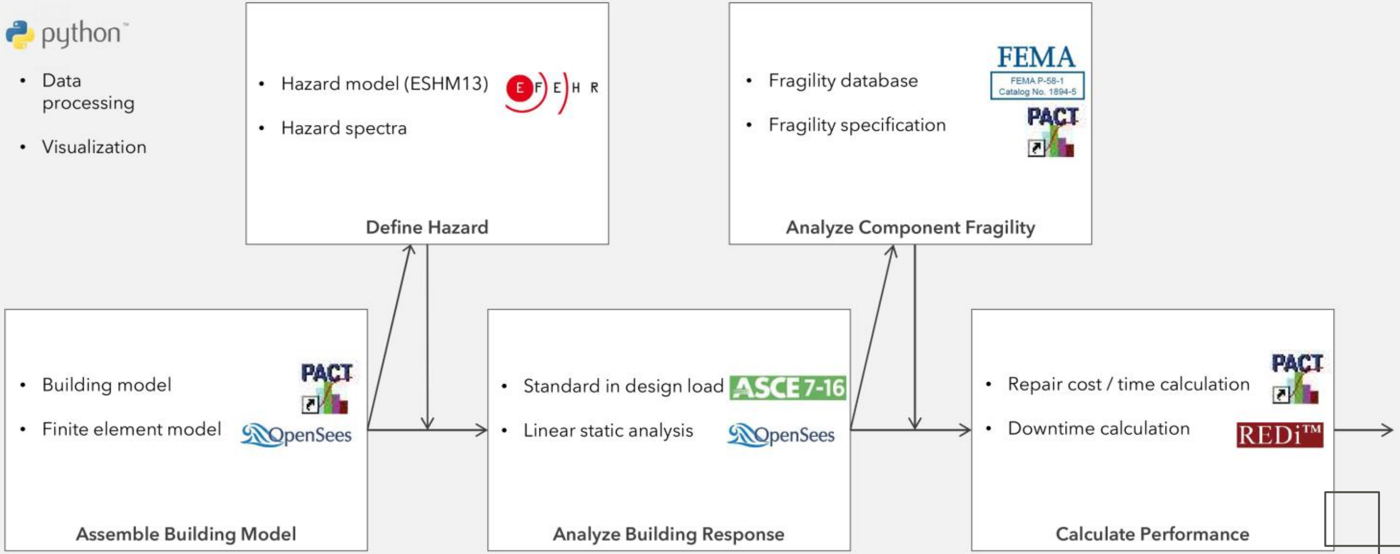
How to Quantify Seismic Resilience?



Source - Kim, K. (2023). Resilience-based Facade Design Framework.

Research gap

- The need for improve the workflow to quantify Resilience analysis
- The need to integrate multi-hazards into the design process

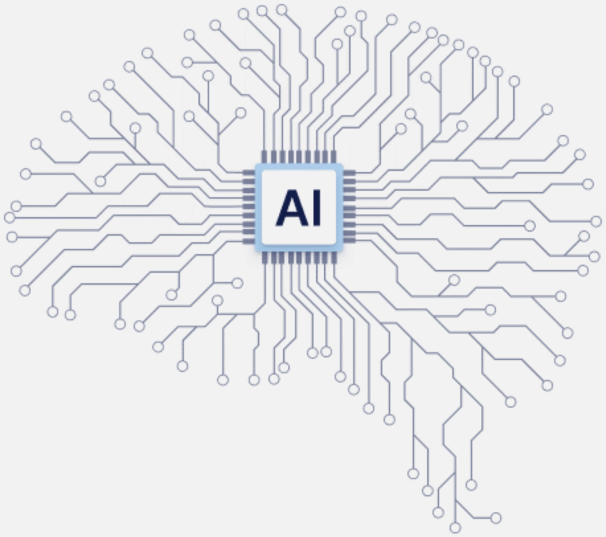
Research Question

- “How can machine learning techniques be effectively applied to improve the workflow of seismic and heat waves resilience analysis in building facades?”

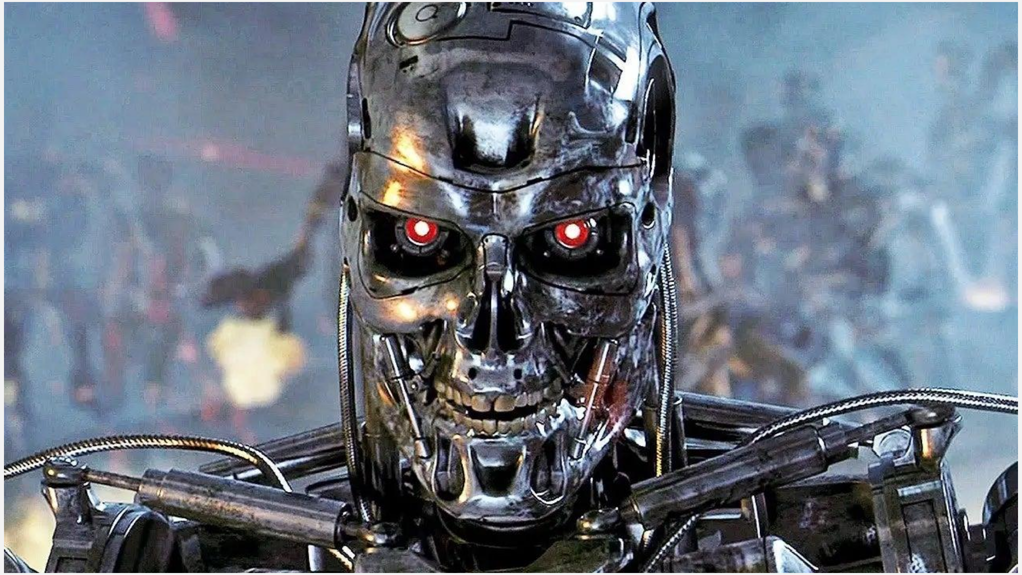
Research sub-Questions

- What simulation techniques can be utilized to achieve accurate results for façade resilience
- How can machine learning enhance the detection and analysis of seismic and thermal risk factors for building facades?
- Which machine learning algorithms best predict building facade resilience to seismic activity and heat waves?
- How can AI synthesize diverse data to provide a resilience score for building facades against heat waves and earthquakes?
- How can machine learning create a user friendly tool for architects and engineers to quickly assess facade resilience against hazards?

Artificial Intelligence!

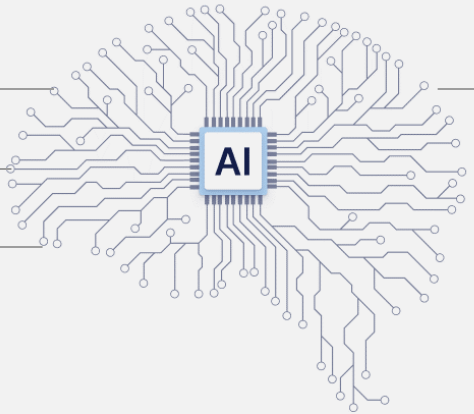


Artificial Intelligence!



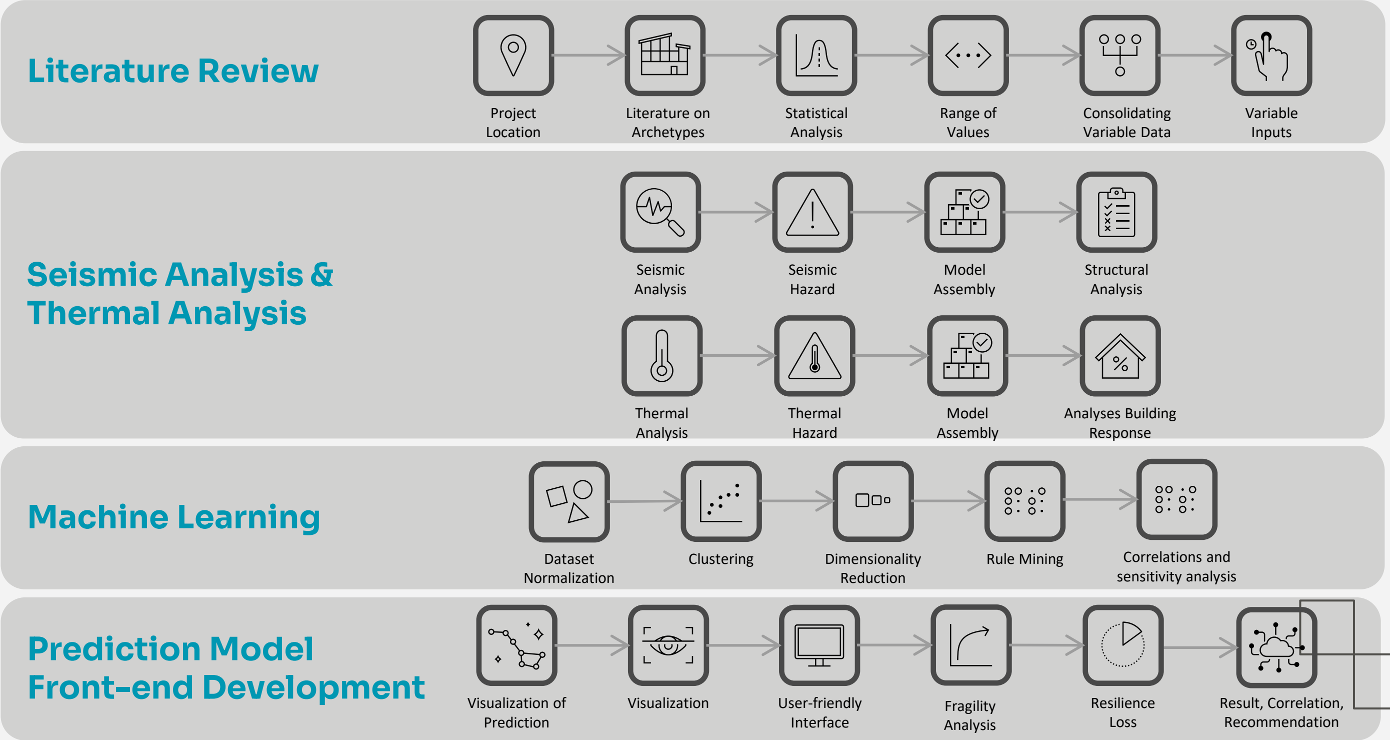
Artificial Intelligence!

- Data for AI to train

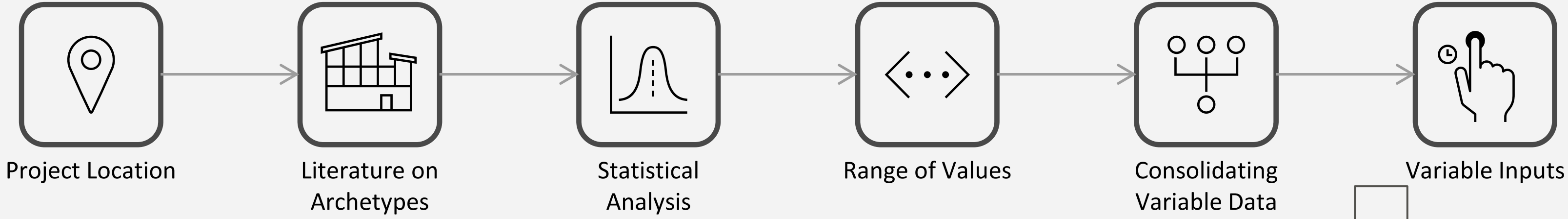


- Giving outputs on the basis of its understanding

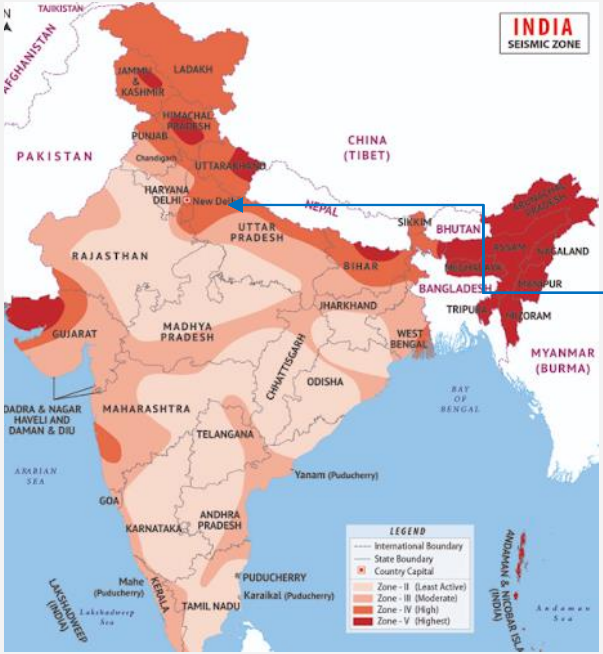
Methodology



Step 1 – Literature review



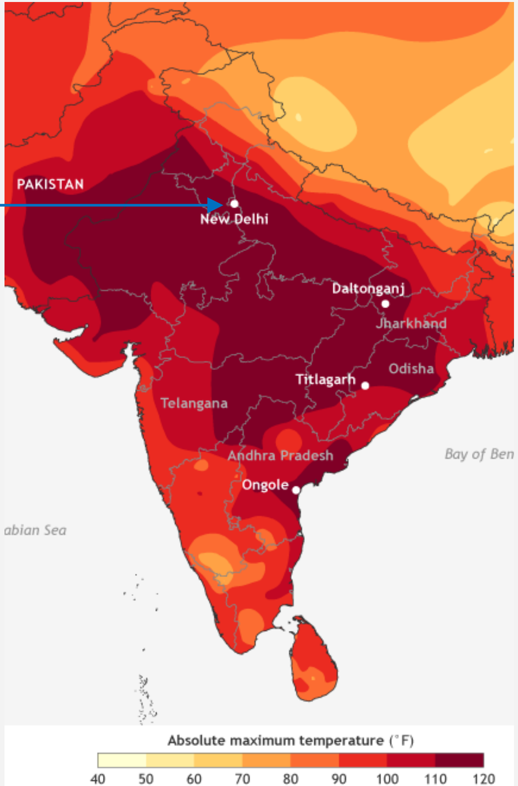
Data Collection Methodology



Seismic zone - IV

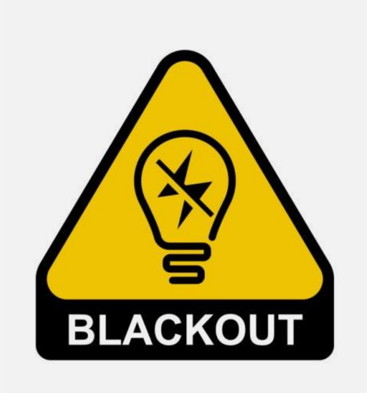
Project Location – New Delhi

Heat wave map



Data Collection Methodology

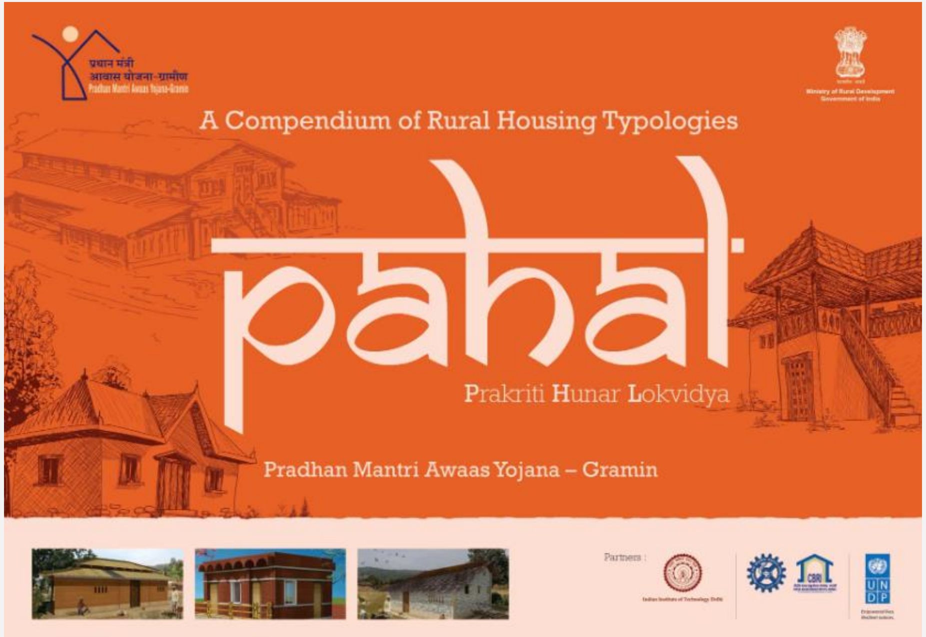
Project Location – New Delhi



In New Delhi, power outages are a significant issue, especially as temperatures soar beyond 45° C

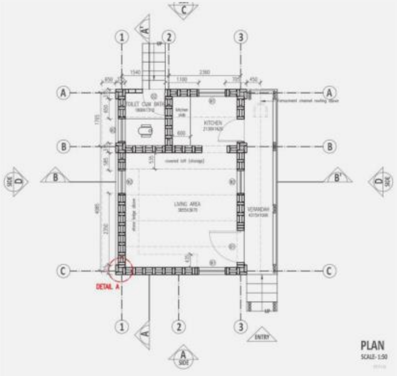
These frequent power outages have a particularly severe impact on residents of low-cost housing and squatter housing In Delhi

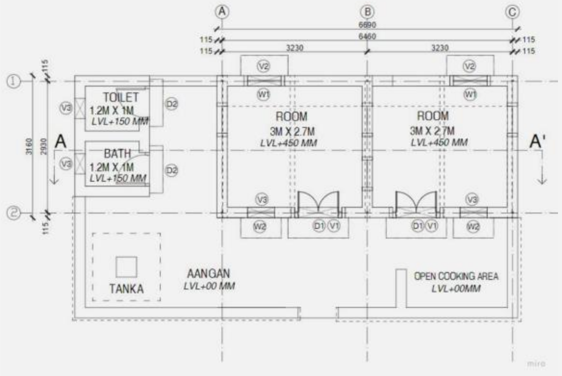
Data Collection Methodology

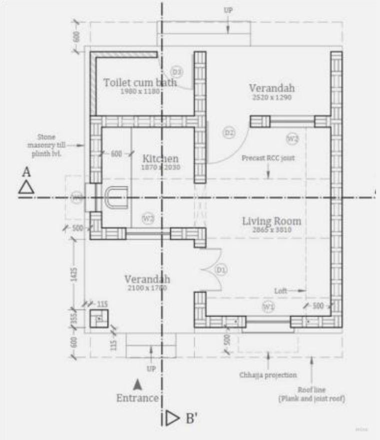


Indian Government's Initiative of providing 10 million low-cost housing to the people of India

Data Collection Methodology







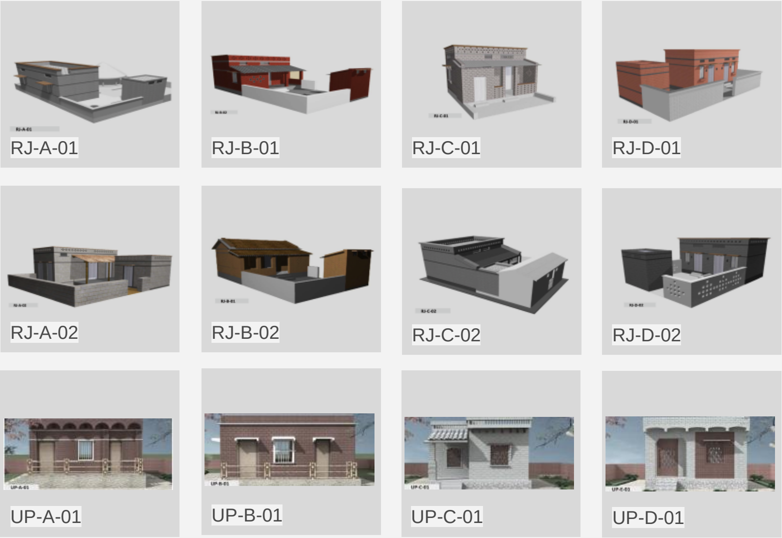
Data Collection Methodology

	Firedclay Brick	Flyash Brick	Concrete Brick	Concrete Block	Calcium Silicate Block	AAC	CLC	CSEB
Tamil Nadu	4	1	-	-	-	-	-	-
Telangana	1	-	-	-	-	-	-	-
Andhra Pradesh	1	-	-	1	-	-	-	-
Maharashtra	2	2	-	-	1	1	1	-
Gujarat	2	1	-	-	-	-	-	-
Bihar	1	1	-	-	-	-	-	-
Delhi & NCT	-	1	-	-	-	-	-	1
Uttar Pradesh	3	-	-	-	-	-	-	-
Madhya Pradesh	1	1	-	-	-	-	-	-
West Bengal	1	1	-	-	-	-	-	-
Haryana	3	1	-	-	-	1	-	-
Karnataka	2	-	-	1	-	-	-	1
Punjab	2	1	1	-	-	-	-	-
Total	23	10	1	2	1	2	1	1

S. N.	Sample	Bulk Density ρ (kg/m³)	Thermal conductivity λ (W/m.K)	Specific heat C_p (J/kg.K)	Compressive strength (MPa)	Water absorption (%)
Hand-moulding						
1	RB01	1599	0.48	907.8	14.83	21
2	RB02	1777	0.60	921.6	16.54	15
3	RB04	1654	0.57	917.5	23.08	19
4	RB06	1887	0.76	927.0	20.23	12
5	RB07	1738	0.53	960.4	7.21	16
6	RB09	1604	0.39	909.0	6.1	23
7	RB10	1512	0.42	926.5	5.32	26
8	RB11	1447	0.50	936.6	10.01	24
9	RB14	1503	0.42	935.9	4.88	26
10	RB15	1264	0.38	927.8	4.16	32
11	RB20	1780	0.55	952.9	18.68	15
12	RB21	1716	0.54	923.1	17.8	17
13	RB23	1819	0.74	978.6	25.8	13

A comprehensive dataset on the properties of various building blocks commonly used in Indian housing was collected

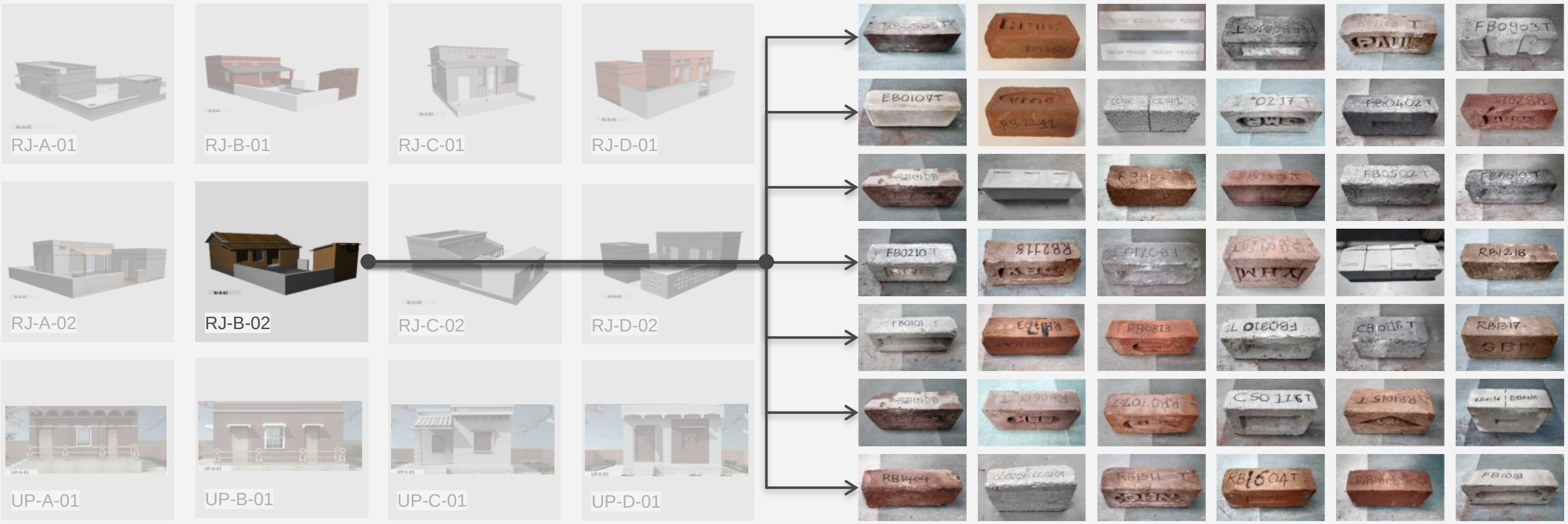
Data Collection Methodology



(a) Buildings

(b) Materials

Data Collection Methodology



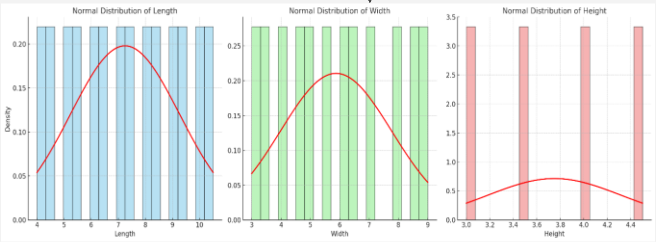
(a) Buildings

(b) Materials

Data Collection Methodology

- wall_thickness
- horizontal_shading
- vertical shading
- Shading_length_meters
- distance_from_lintel
- angle_of_inclination
- window_to_wall_ratio

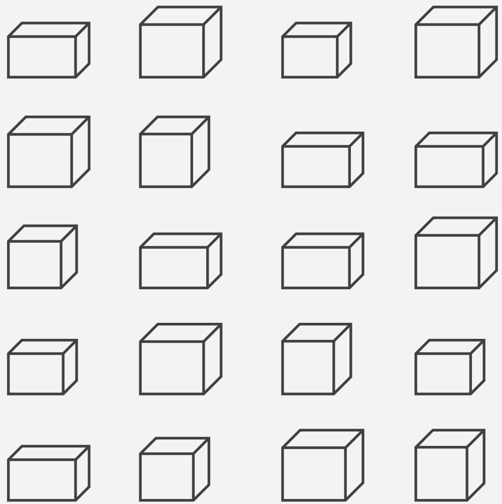
Statistical Analysis



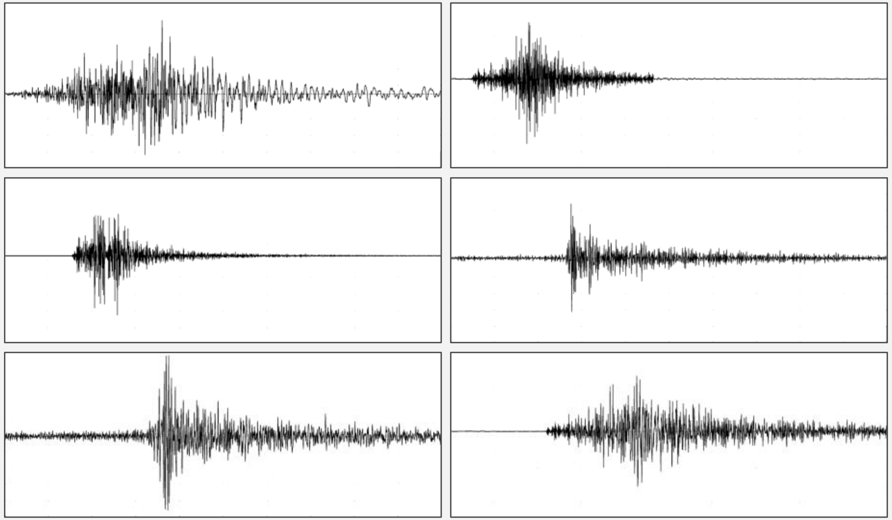
671 different geometrical configurations

Length	Width	Height
4	3	3
4	3	3.5
4	3	4
4	3	4.5
4	3.5	3
4	3.5	3.5
4	3.5	4
4	3.5	4.5
4	4	3
4	4	3.5
4	4	4
4	4	4.5
4	4.5	3
4	4.5	3.5
4	4.5	4
4	4.5	4.5
4	5	3
4	5	3.5
4	5	4
4	5	4.5
4	5.5	3
4	5.5	3.5
4	5.5	4
4	5.5	4.5
4	6	3
4	6	3.5

Data Collection Methodology

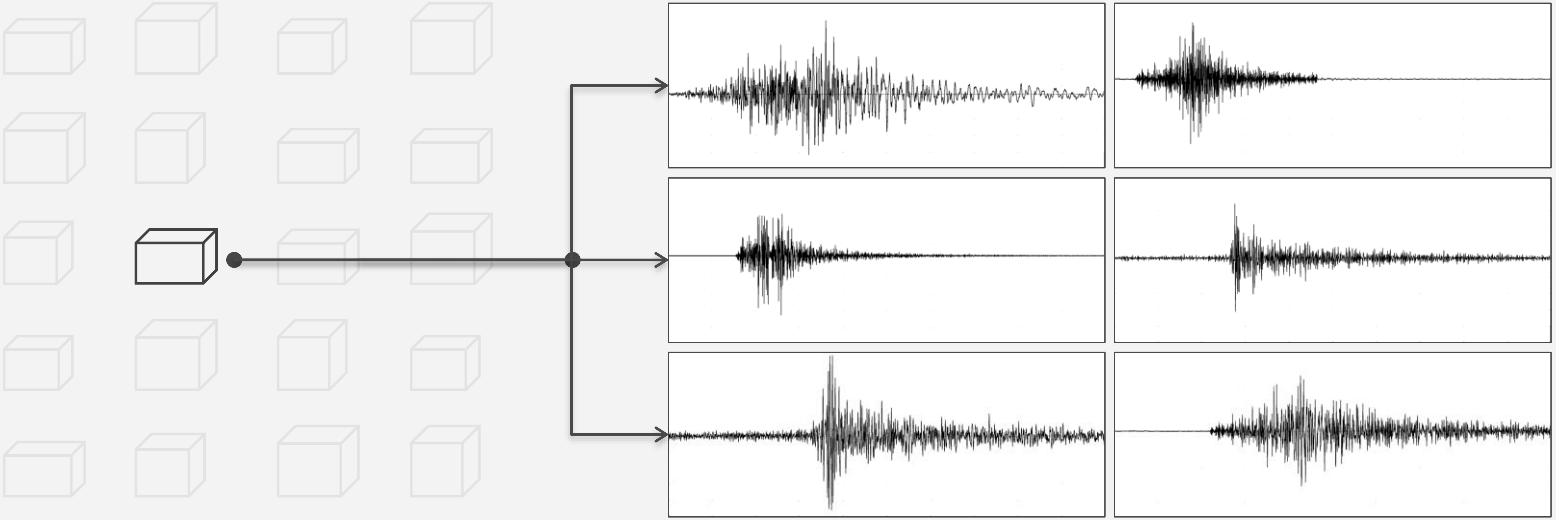


(a) Dimensions



(b) Earthquake Data

Data Collection Methodology



(a) Dimensions

(b) Earthquake Data

Data Collection Methodology

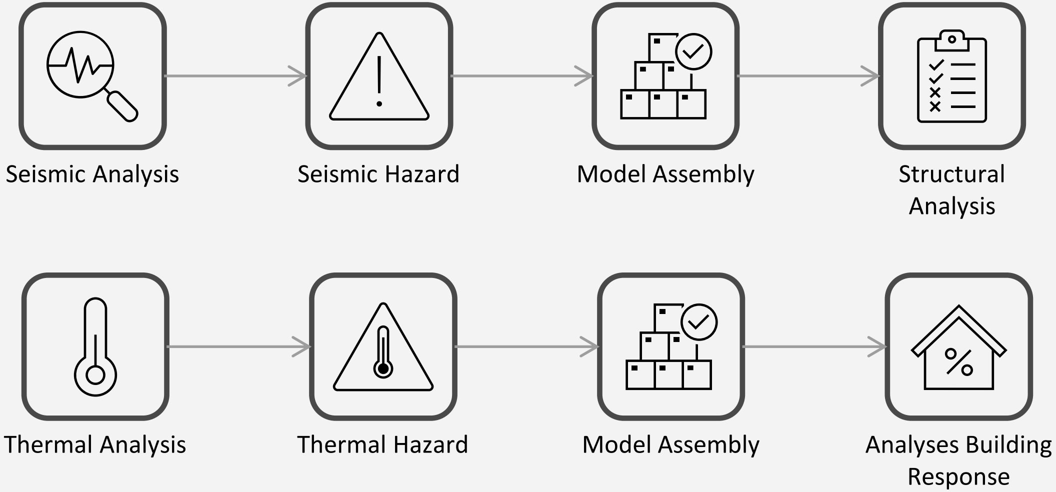
All the variable inputs required for conducting the simulations

- wall_thickness
- horizontal_shading
- vertical_shading
- Shading_length_meters
- distance_from_lintel
- angle_of_inclination
- window_to_wall_ratio
- _indoor_air_speed
- dis_coefficient
- Living_area_meters
- thermal_absorbance
- thermal_conductivity
- Bulk density
- Specific_heat
- Block_type
- space_height
- Orientation
- Building Dimensions

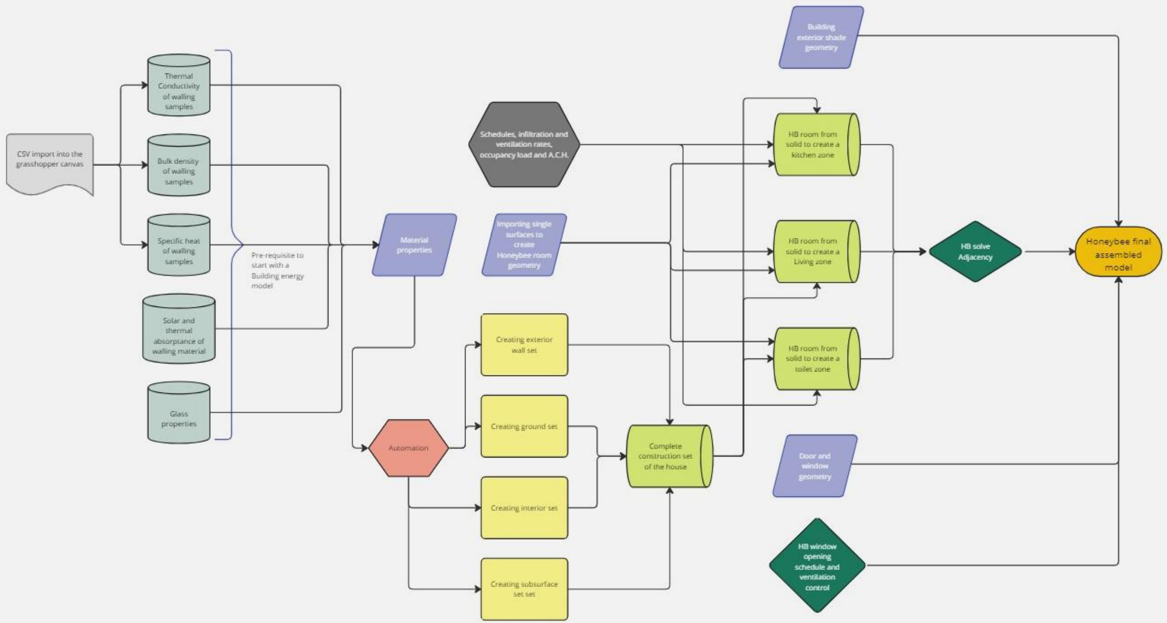
Outputs

- Spatial Thermal Autonomy
- Inter-storey drift angles

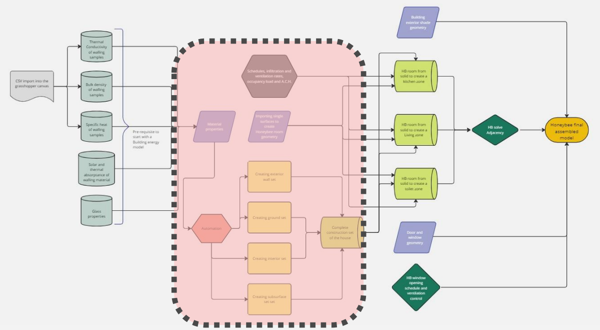
Simulations

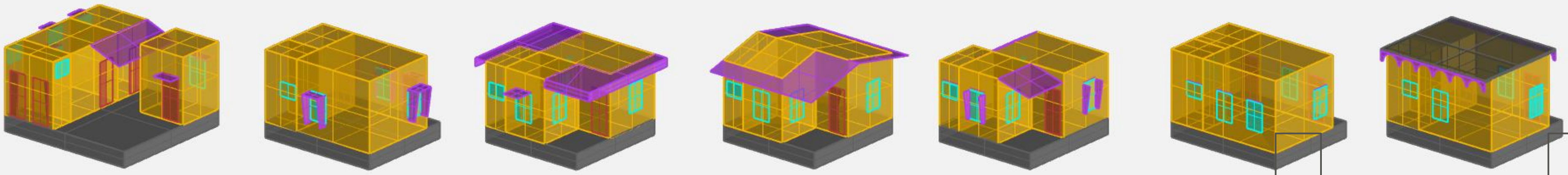


Thermal Simulations

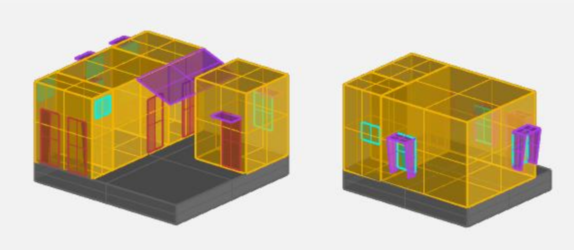


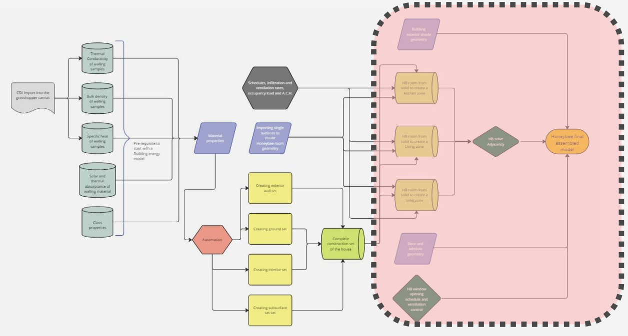
Thermal Simulations





Thermal Simulations

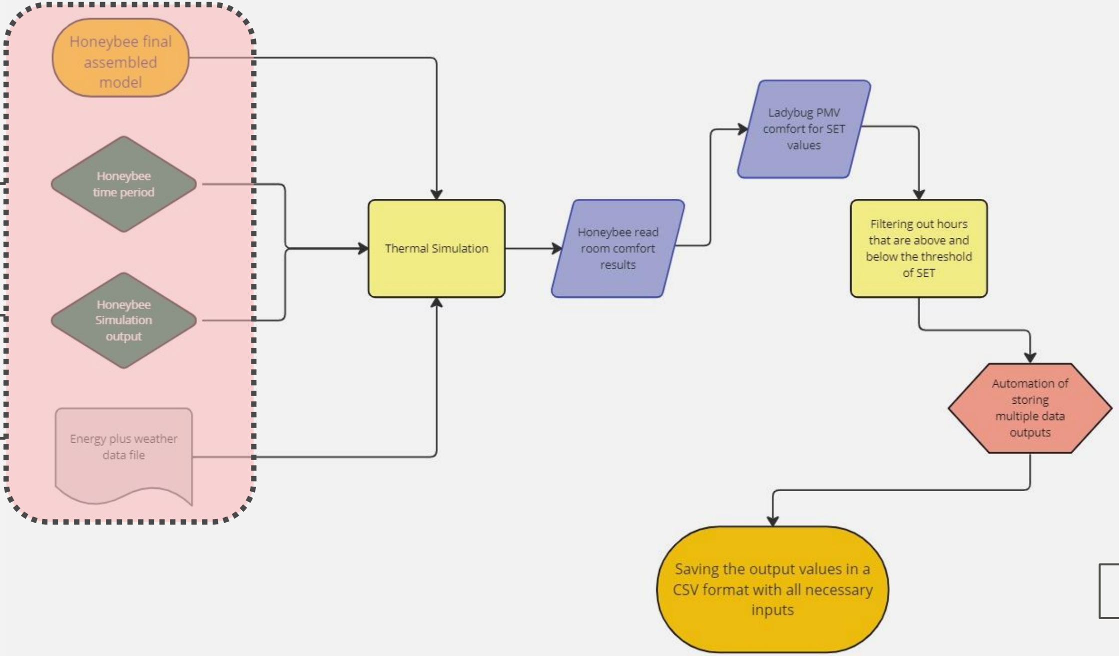




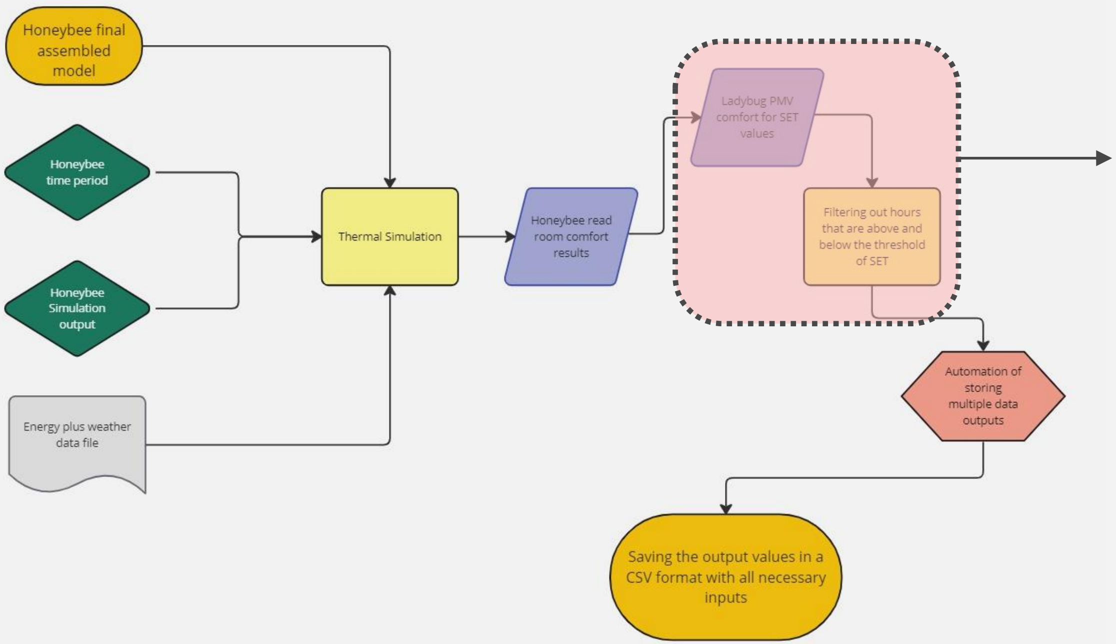
- Building program
- No-HVAC system
- Ventilation control
- A.C.H. for each zone
- Occupancy rate
- Schedules

Thermal Simulations

- Analysis period for summer season
- Comfort levels, Surface_temperatues
- EPW file of TMY of 2022

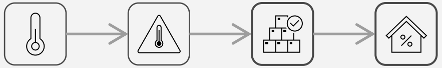


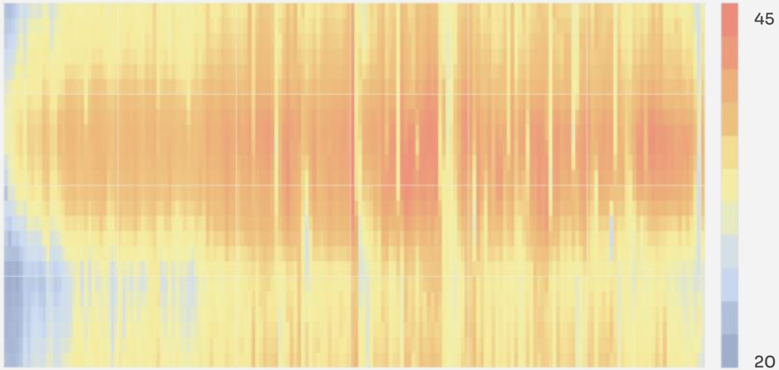
Thermal Simulations



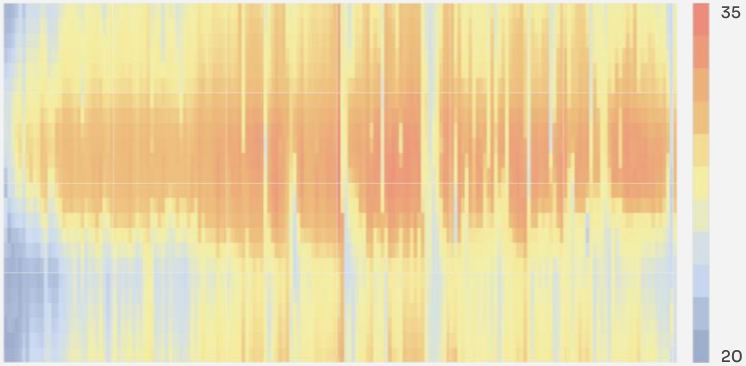
Calculating SET values and using that to achieve Spatial thermal autonomy

Thermal Simulations





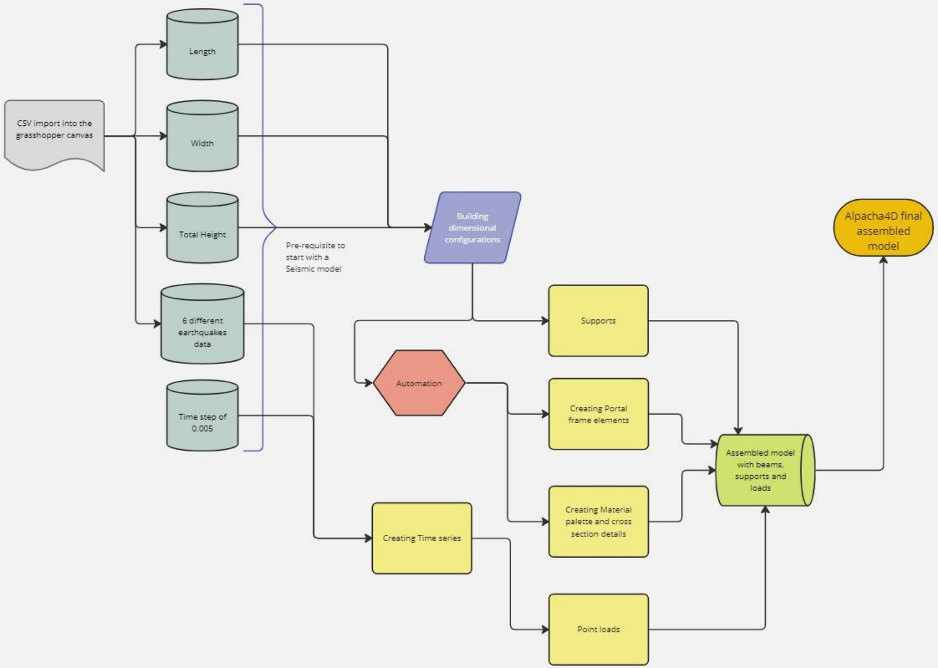
Baseline Model
Hourly plot



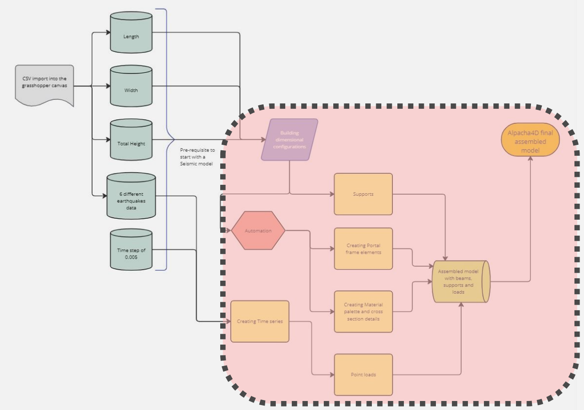
Model with higher performance

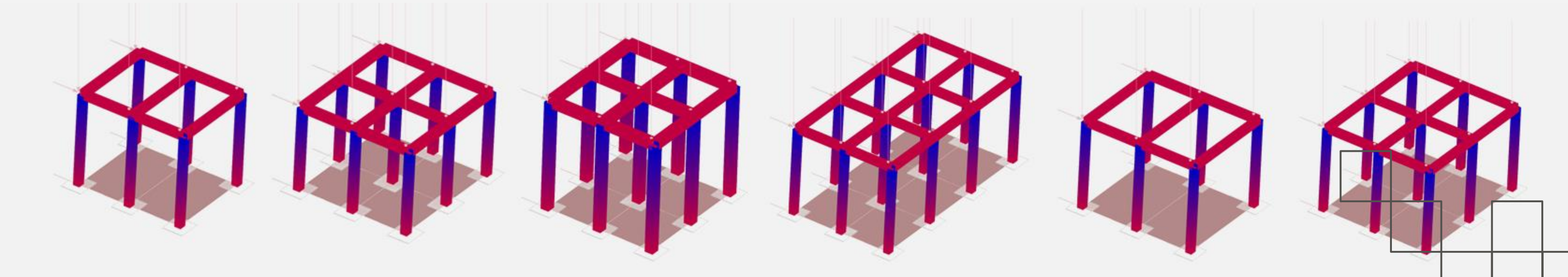
Seismic Simulations

Workflow for a linear static analysis

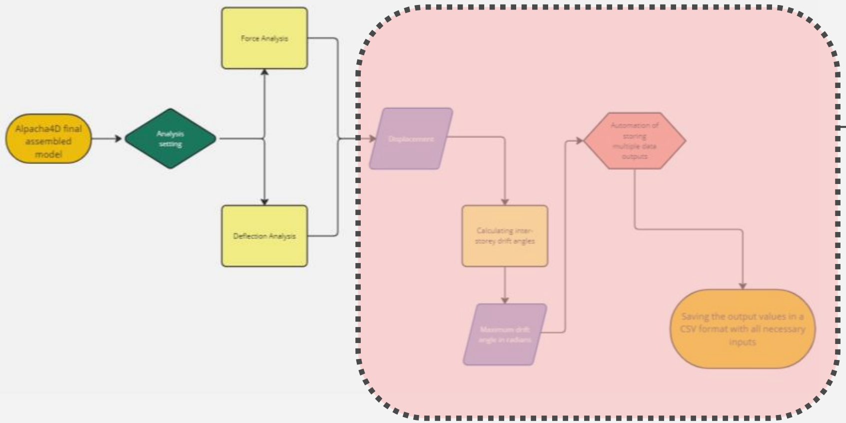


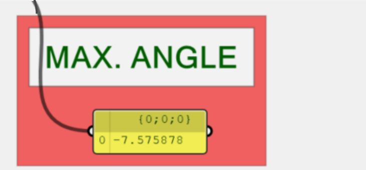
Seismic Simulations





Seismic Simulations





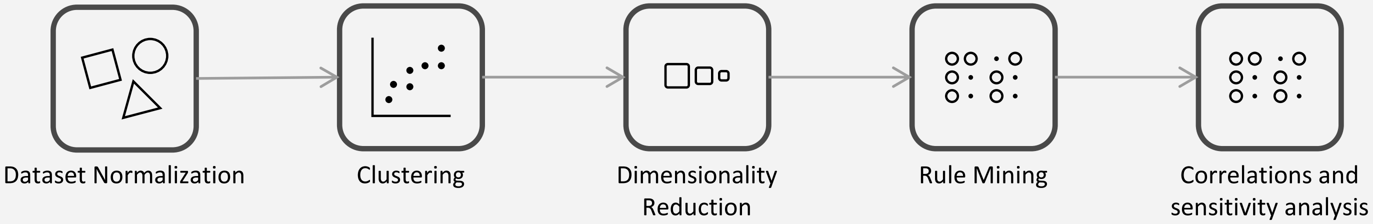
Inter-storey drift angles, to convert them to radians

Simulations results

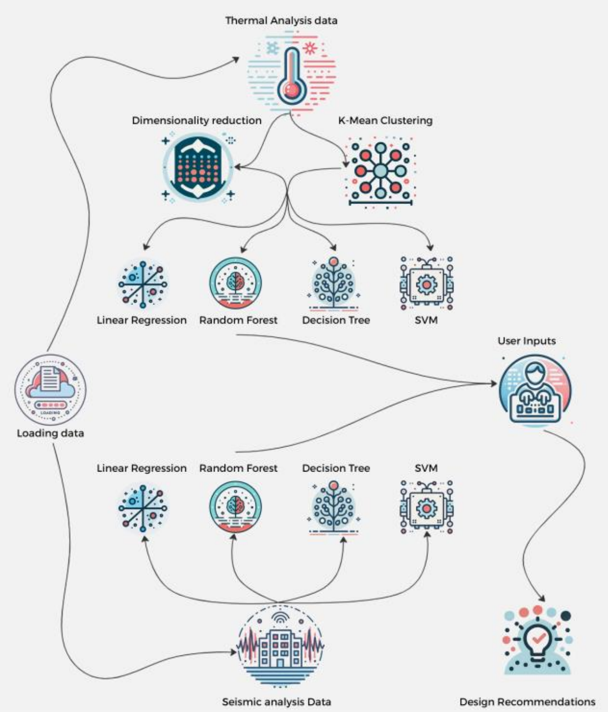
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Thermal_autonomy	wall_thickness	horizontal_shading	vertical_shading	Shading_length_meters	distance_from_lintel	angle_of_inclination	window_to_wall_ratio	_indoor_air_speed	dis_coefficient	Living_area_meters	thermal_absorbance	thermal_conductivity	Bulk density	Specific_heat	Block_type	space_height	Orientation
2	67.81427	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.48	1599	907	RB01	3.35	South
3	71.98188	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.6	1777	921	RB02	3.35	South
4	71.95923	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.57	1654	917	RB04	3.35	South
5	71.596829	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.76	1887	927	RB06	3.35	South
6	72.14043	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.53	1738	960	RB07	3.35	South
7	72.797282	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.39	1604	909	RB09	3.35	South
8	72.661382	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.42	1512	926	RB10	3.35	South
9	72.298981	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.5	1447	936	RB11	3.35	South
10	72.684032	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.42	1503	935	RB14	3.35	South
11	72.729332	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.38	1264	927	RB15	3.35	South
12	72.14043	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.55	1780	952	RB20	3.35	South
13	72.11778	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.54	1716	923	RB21	3.35	South
14	71.755379	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.74	1819	978	RB23	3.35	South
15	71.121178	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.97	2119	916	RB03	3.35	South
16	70.600227	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	1.12	2028	955	RB05	3.35	South
17	71.460929	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.8	1975	928	RB12	3.35	South
18	72.14043	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.58	1895	924	RB18	3.35	South
19	71.89128	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.67	1958	947	RB19	3.35	South
20	72.04983	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.59	1807	934	RB13	3.35	South
21	72.797282	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.42	1657	940	RB16	3.35	South
22	72.797282	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.41	1648	927	RB17	3.35	South
23	71.82333	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.64	1798	918	RB22	3.35	South
24	72.298981	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.51	1737	946	RB08	3.35	South
25	71.257078	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.86	1878	938	FB01	3.35	South
26	71.302378	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.8	1844	924	FB02	3.35	South
27	72.16308	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.53	1475	962	FB03	3.35	South
28	72.706682	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.39	1299	924	FB04	3.35	South
29	72.480181	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.5	1807	961	FB05	3.35	South
30	72.933182	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.36	1543	908	FB06	3.35	South
31	71.93658	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.67	2048	976	FB07	3.35	South
32	72.253681	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.52	1682	936	FB08	3.35	South
33	71.89128	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.65	1989	929	FB09	3.35	South
34	72.366931	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.5	1722	925	FB10	3.35	South
35	73.023783	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.17	608	875	AB01	3.35	South
36	72.955832	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.19	623	831	AB02	3.35	South
37	71.98188	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.59	1630	908	EB01	3.35	South
38	71.596829	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.75	1773	934	EB02	3.35	South
39	71.392978	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.81	2023	912	CC01	3.35	South
40	71.84598	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.66	1961	928	CC02	3.35	South
41	69.173273	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	1.55	2122	920	CB01	3.35	South
42	71.84598	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.71	2071	969	CS01	3.35	South
43	73.069083	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.2	0.19	693	932	CL01	3.35	South
44	62.355606	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.4	0.48	1599	907	RB01	3.35	South
45	61.472254	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.4	0.6	1777	921	RB02	3.35	South
46	61.494904	0.35	yes	no	0.6	0.2	0	10	1.2	0.7	14	0.4	0.57	1654	917	RB04	3.35	South

Results for more than 2500 thermal simulations and 3000 seismic simulations are stored in a CSV file to be used for machine learning

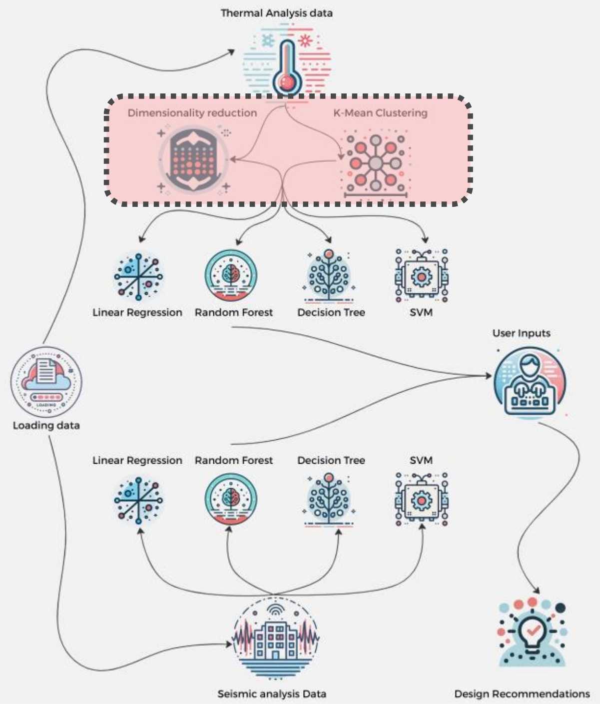
Machine learning model

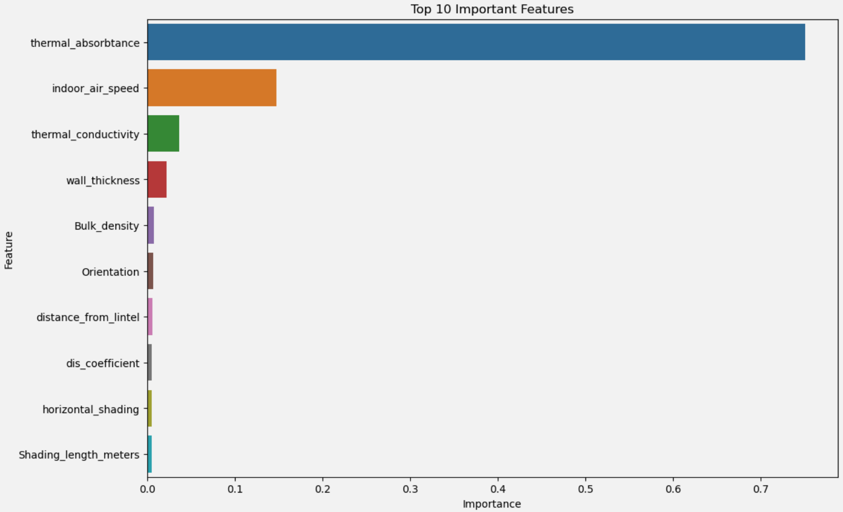


Machine learning model

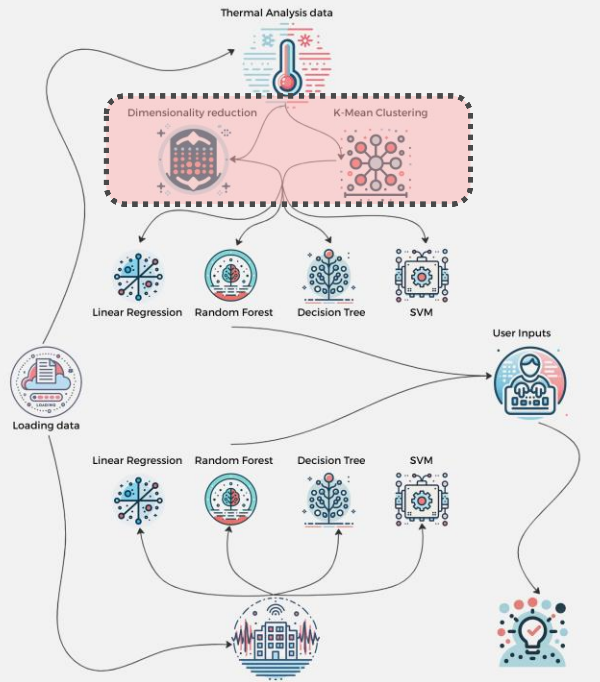


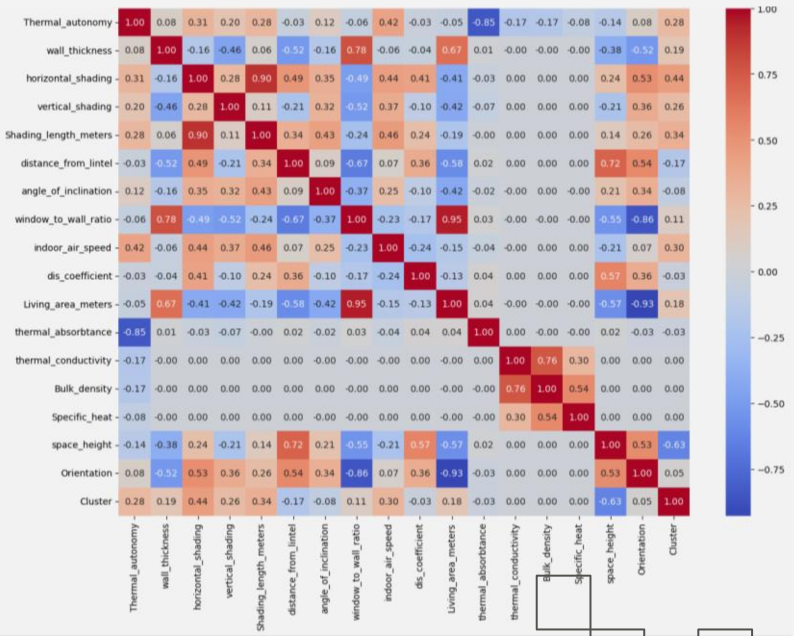
Machine learning model





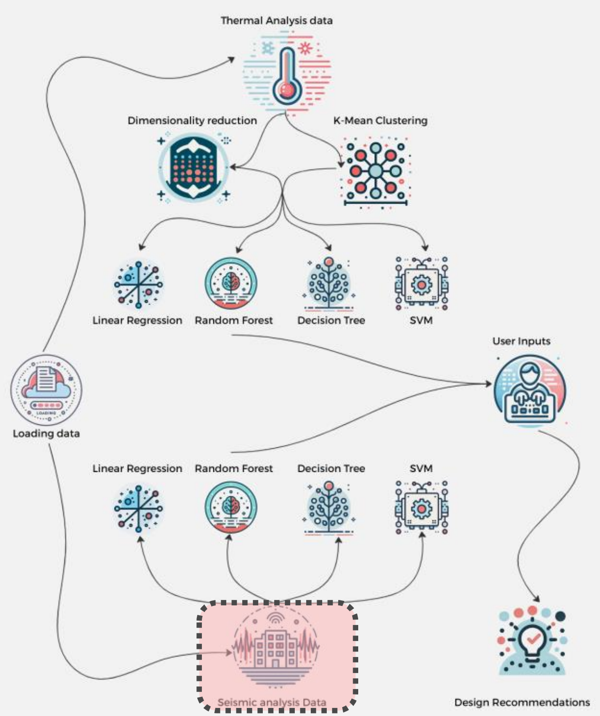
Machine learning model

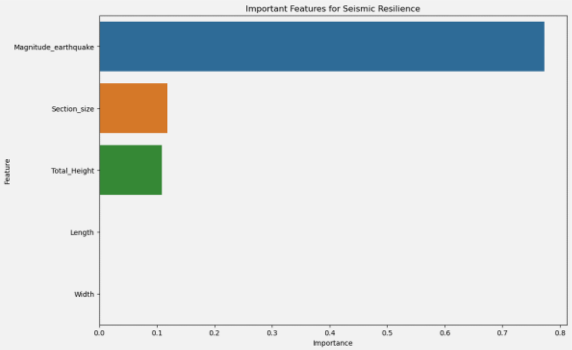


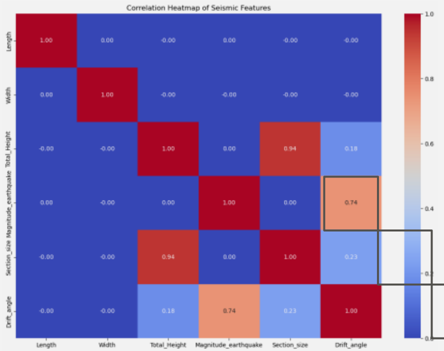


	Thermal_autonomy	wall_thickness	horizontal_shading	vertical_shading	Shading_length_meters	distance_from_lintel	angle_of_inclination	window_to_wall_ratio	indoor_air_speed	dis_coefficient	Living_area_meters	thermal_absorbtance	thermal_conductivity	Bulk_density	Specific_heat	space_height	Orientation	Cluster
Thermal_autonomy	1.00	0.08	0.31	0.20	0.28	-0.03	0.12	-0.06	0.42	-0.03	-0.05	-0.85	-0.17	-0.17	-0.08	-0.14	0.08	0.28
wall_thickness	0.08	1.00	-0.16	-0.46	0.06	-0.52	-0.16	0.78	-0.06	-0.04	0.67	0.01	-0.00	-0.00	-0.00	-0.38	-0.52	0.19
horizontal_shading	0.31	-0.16	1.00	0.28	0.90	0.49	0.35	-0.49	0.44	0.41	-0.41	-0.03	0.00	0.00	0.00	0.24	0.53	0.44
vertical_shading	0.20	-0.46	0.28	1.00	0.11	-0.21	0.32	-0.52	0.37	-0.10	-0.42	-0.07	0.00	0.00	0.00	-0.21	0.36	0.26
Shading_length_meters	0.28	0.06	0.90	0.11	1.00	0.34	0.43	-0.24	0.46	0.24	-0.19	-0.00	0.00	0.00	0.00	0.14	0.26	0.34
distance_from_lintel	-0.03	-0.52	0.49	-0.21	0.34	1.00	0.09	-0.67	0.07	0.36	-0.58	0.02	0.00	0.00	0.00	0.72	0.54	-0.17
angle_of_inclination	0.12	-0.16	0.35	0.32	0.43	0.09	1.00	-0.37	0.25	-0.10	-0.42	-0.02	-0.00	0.00	-0.00	0.21	0.34	-0.08
window_to_wall_ratio	-0.06	0.78	-0.49	-0.52	-0.24	-0.67	-0.37	1.00	-0.23	-0.17	0.95	0.03	-0.00	-0.00	-0.00	-0.55	-0.86	0.11
indoor_air_speed	0.42	-0.06	0.44	0.37	0.46	0.07	0.25	-0.23	1.00	-0.24	-0.15	-0.04	-0.00	0.00	0.00	-0.21	0.07	0.30
dis_coefficient	-0.03	-0.04	0.41	-0.10	0.24	0.36	-0.10	-0.17	-0.24	1.00	-0.13	0.04	0.00	0.00	0.00	0.57	0.36	-0.03
Living_area_meters	-0.05	0.67	-0.41	-0.42	-0.19	-0.58	-0.42	0.95	-0.15	-0.13	1.00	0.04	-0.00	-0.00	-0.00	-0.57	-0.93	0.18
thermal_absorbtance	-0.85	0.01	-0.03	-0.07	-0.00	0.02	-0.02	0.03	-0.04	0.04	0.04	1.00	0.00	-0.00	-0.00	0.02	-0.03	-0.03
thermal_conductivity	-0.17	-0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	0.00	-0.00	0.00	1.00	0.76	0.30	0.00	0.00	0.00
Bulk_density	-0.17	-0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	-0.00	-0.00	0.76	1.00	0.54	0.00	0.00	0.00
Specific_heat	-0.08	-0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00	0.30	0.54	1.00	0.00	0.00	0.00
space_height	-0.14	-0.38	0.24	-0.21	0.14	0.72	0.21	-0.55	-0.21	0.57	-0.57	0.02	0.00	0.00	0.00	1.00	0.53	-0.63
Orientation	0.08	-0.52	0.53	0.36	0.26	0.54	0.34	-0.86	0.07	0.36	-0.93	-0.03	0.00	0.00	0.00	0.53	1.00	0.05
Cluster	0.28	0.19	0.44	0.26	0.34	-0.17	-0.08	0.11	0.30	-0.03	0.18	-0.03	0.00	0.00	0.00	-0.63	0.05	1.00

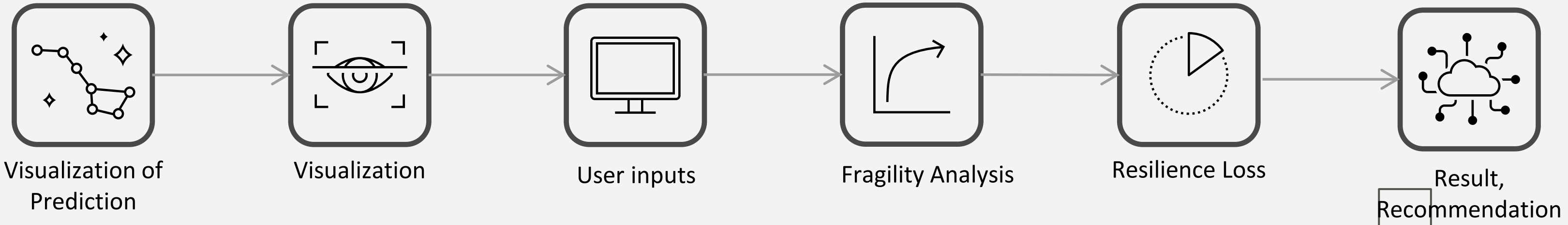
Machine learning model



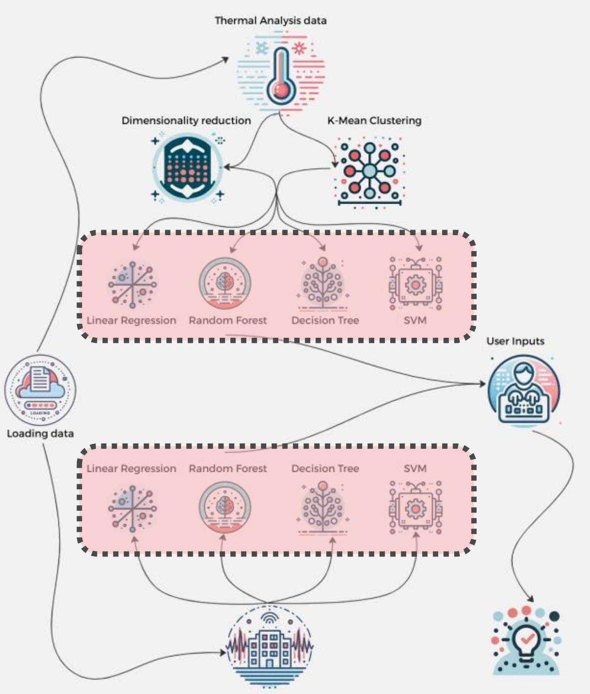


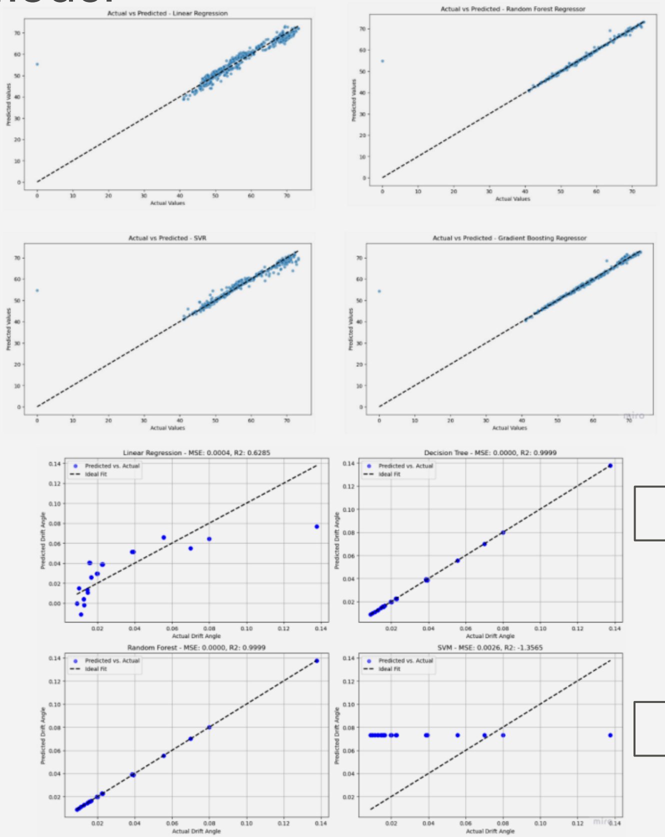


Supervised Machine Learning Prediction model

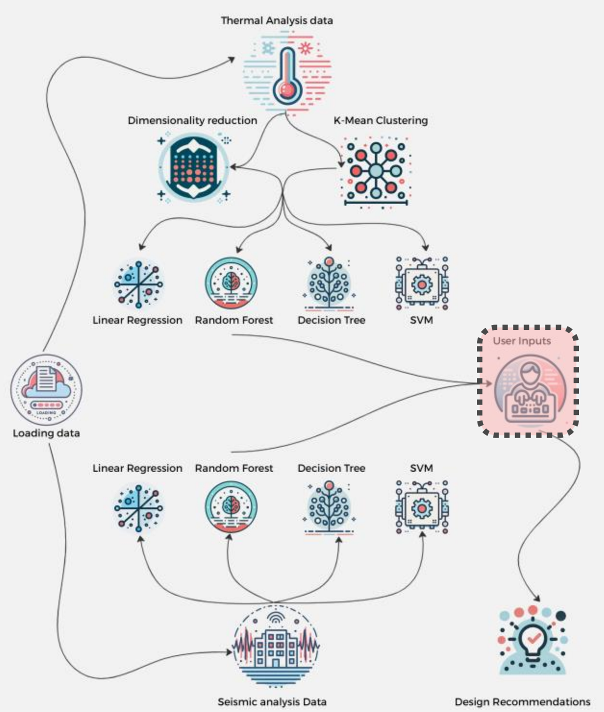


Supervised Machine Learning Prediction model





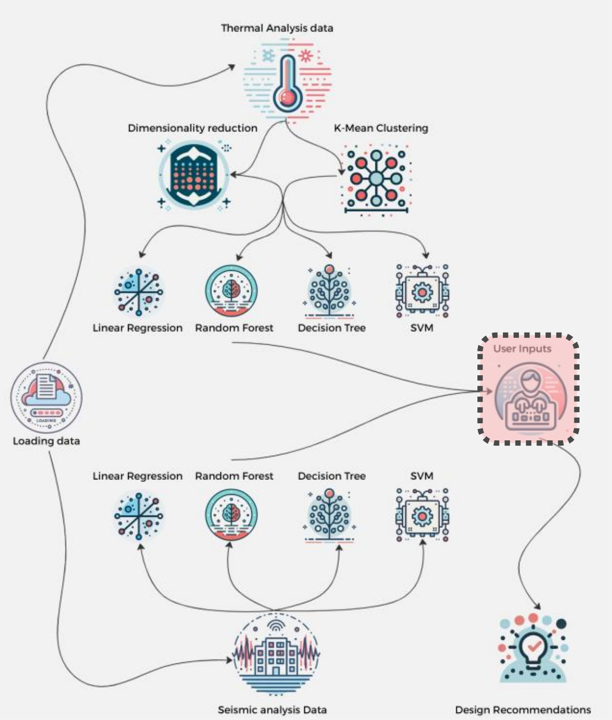
Prediction model for thermal Resilience




```
Please enter the following details for thermal autonomy prediction:
Wall thickness (in meters): 0.35
Horizontal shading (1 for present, 0 for absent): 1
Vertical shading (1 for present, 0 for absent): 0
Shading length (in meters): 0.6
Distance from shading (in meters): 0.2
Angle of inclination (in degrees): 0
Window to wall ratio (as percentage): 10
Indoor air speed (in m/s): 0.8
Discharge coefficient: 0.6
Living area (in square meters): 14
Thermal absorbance (0-1): 0.8
Specific heat of the material: 950
Thermal conductivity of the material (in W/mK): 0.48
Bulk density of the material (in kg/m3): 1599
Space height (in meters): 3.35
Orientation (degrees relative to north): 180
```

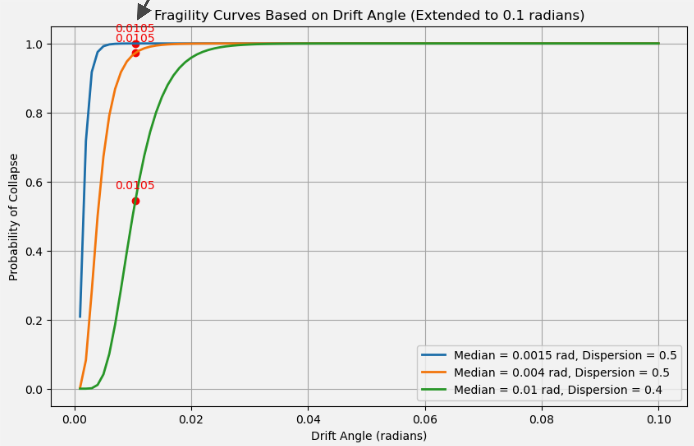
```
Predicted thermal autonomy: 47.27%
```

Prediction model for Seismic Resilience




```
Please enter the following parameters for drift angle prediction:
Enter Length: 4
Enter Width: 4
Enter Total Height: 3.35
Enter Magnitude of Earthquake: 5.5
Enter Section Size: 0.35
```

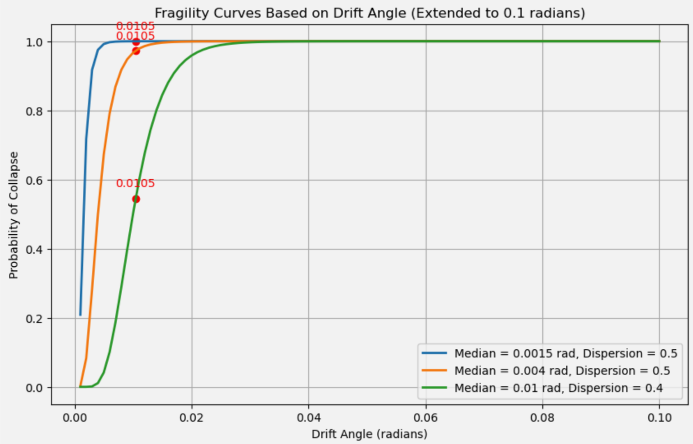
```
Predicted Drift Angle: 0.0105
```

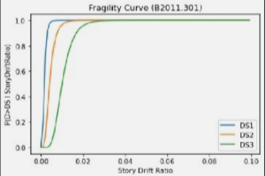


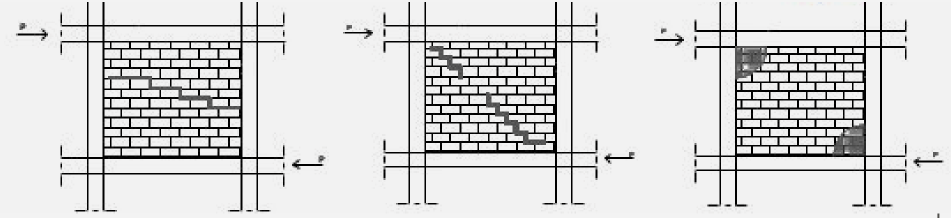
Prediction model for Seismic Resilience

```
Please enter the following parameters for drift angle prediction:
Enter Length: 4
Enter Width: 4
Enter Total Height: 3.35
Enter Magnitude of Earthquake: 5.5
Enter Section Size: 0.35
```

```
Predicted Drift Angle: 0.0105
```



B2011.301	Exterior Wall - Masonry infills with French window and Partitions with door				
	DS1	Detachment of infill, Light diagonal cracking	0.0015	0.5	
	DS2	Extensive diagonal cracking	0.004	0.5	
	DS3	Corner crushing and sliding of mortar joints	0.01	0.4	

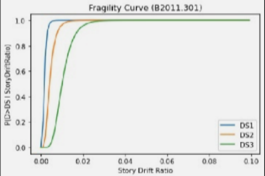


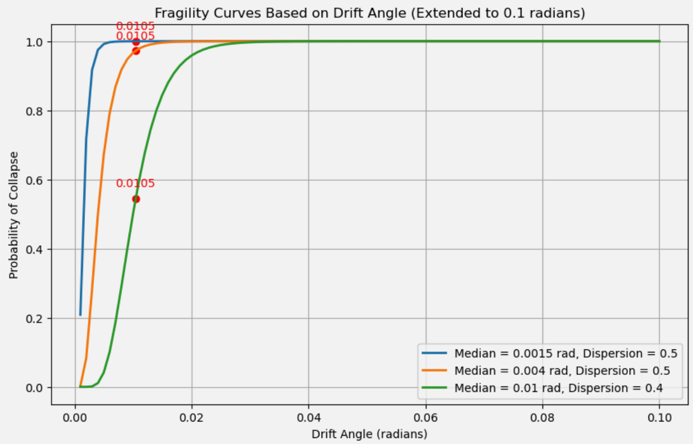
DS1 DS2 DS3

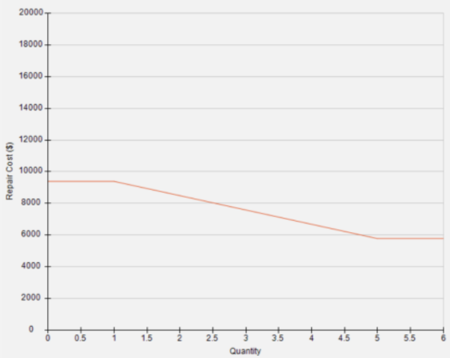
Prediction model for Seismic Resilience

```
Please enter the following parameters for drift angle prediction:
Enter Length: 4
Enter Width: 4
Enter Total Height: 3.35
Enter Magnitude of Earthquake: 5.5
Enter Section Size: 0.35
```

```
Predicted Drift Angle: 0.0105
```

B2011.301	Exterior Wall - Masonry infills with French window and Partitions with door				
 int ext	DS1	Detachment of infill, Light diagonal cracking	0.0015	0.5	
	DS2	Extensive diagonal cracking	0.004	0.5	
	DS3	Corner crushing and sliding of mortar joints	0.01	0.4	



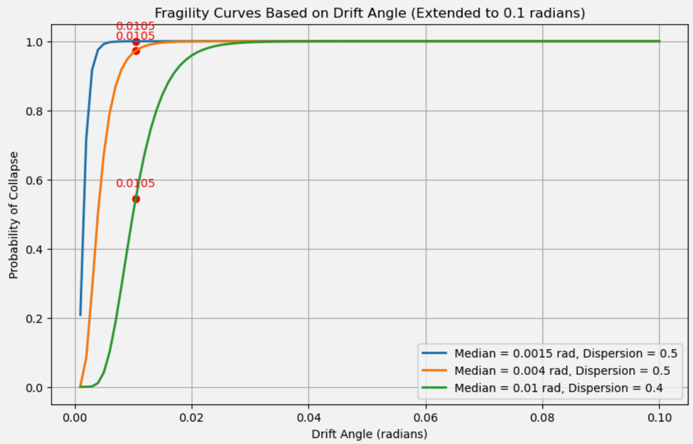


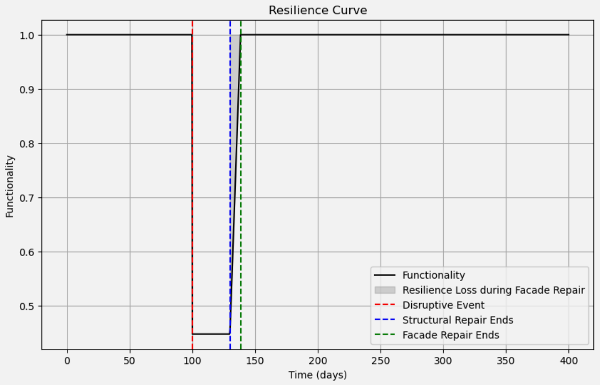
Estimated Economic Loss: 859751.05 INR

Prediction model for Seismic Resilience

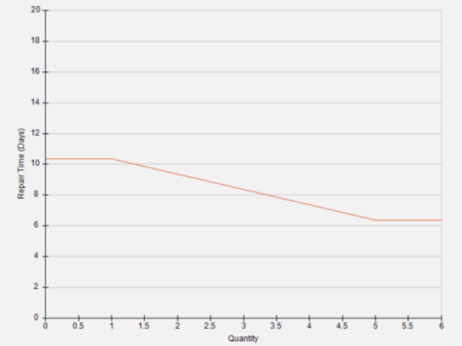
```
Please enter the following parameters for drift angle prediction:
Enter Length: 4
Enter Width: 4
Enter Total Height: 3.35
Enter Magnitude of Earthquake: 5.5
Enter Section Size: 0.35
```

```
Predicted Drift Angle: 0.0105
```





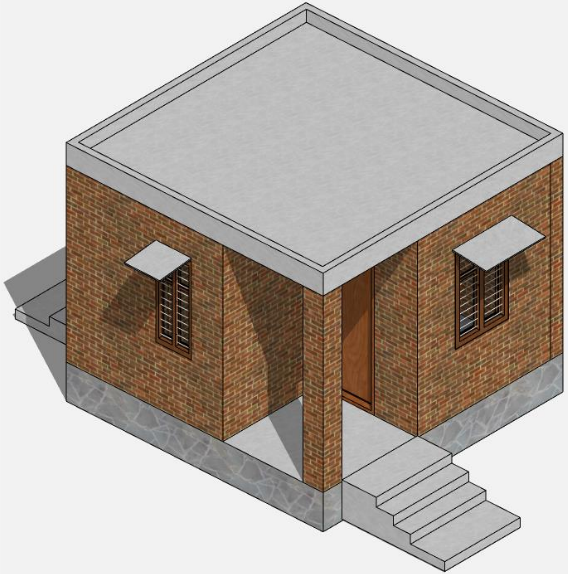
Total estimated repair time (structural + facade repair): 38.5 days Facade repair time: 8.5 days
Initial functionality drop: 0.55



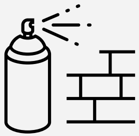
Thermal Recommendations

```
Please enter the following details for thermal autonomy prediction:
Wall thickness (in meters): 0.35
Horizontal shading (1 for present, 0 for absent): 1
Vertical shading (1 for present, 0 for absent): 0
Shading length (in meters): 0.6
Distance from shading (in meters): 0.2
Angle of inclination (in degrees): 0
Window to wall ratio (as percentage): 10
Indoor air speed (in m/s): 0.8
Discharge coefficient: 0.6
Living area (in square meters): 14
Thermal absorbance (0-1): 0.8
Specific heat of the material: 950
Thermal conductivity of the material (in W/mK): 0.48
Bulk density of the material (in kg/m3): 1599
Space height (in meters): 3.35
Orientation (degrees relative to north): 180
```

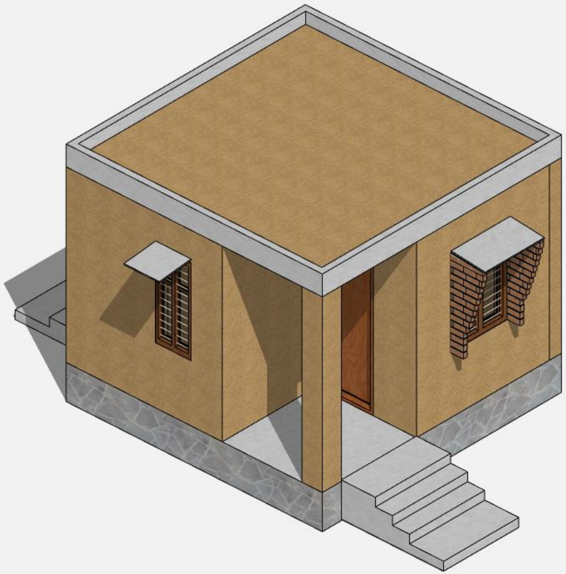
```
Predicted thermal autonomy: 47.27%
```



Thermal Recommendations

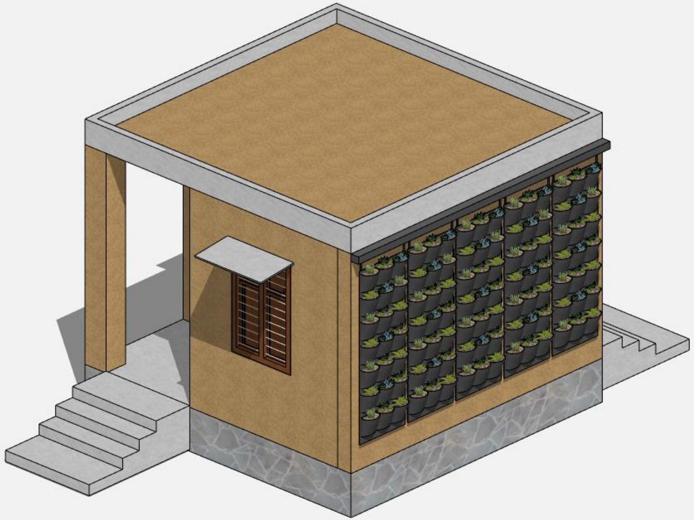


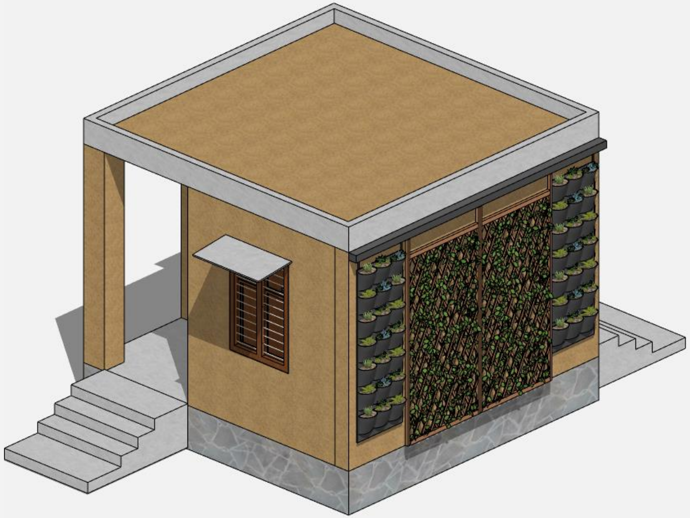
Reflective coating with local material like , like Mud Phuska,
Reduces thermal absorptance
Up to 0.3



Thermal Recommendations

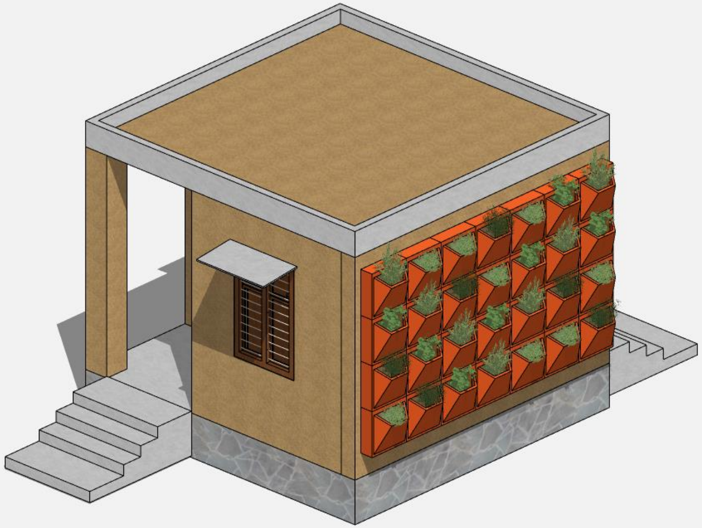
Cheap green façade





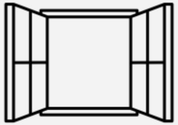
Thermal Recommendations

A Second layer of cladding with local materials, Like Terracotta tiles

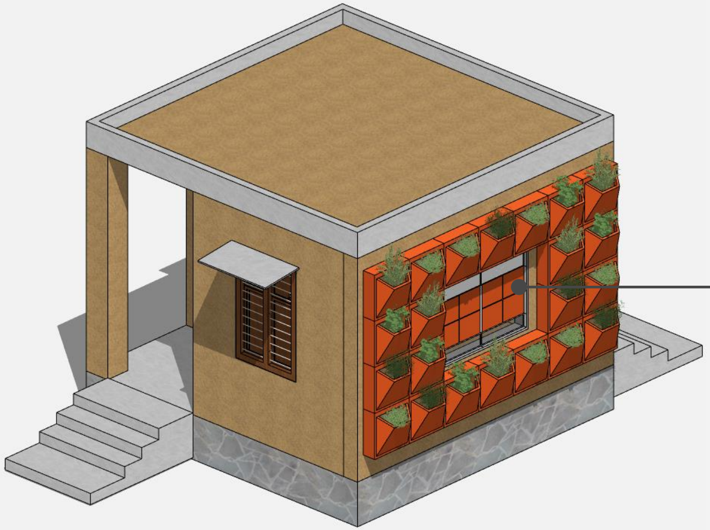


Thermal Recommendations

Passive evaporative cooling

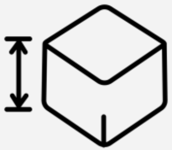


Use of natural vents

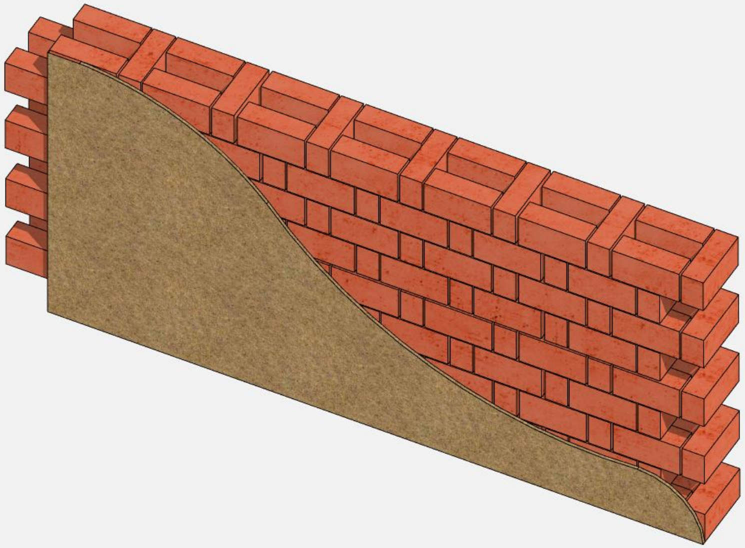


cSNAP - An alternative cooling method called evaporative cooling (EC) uses up to 75% less energy than vapor-compression systems. In development under Harvard University

Thermal Recommendations

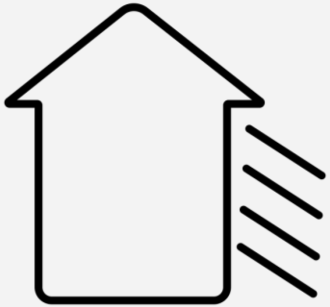


Increase wall thickness by using Rat- trap bond for wall construction



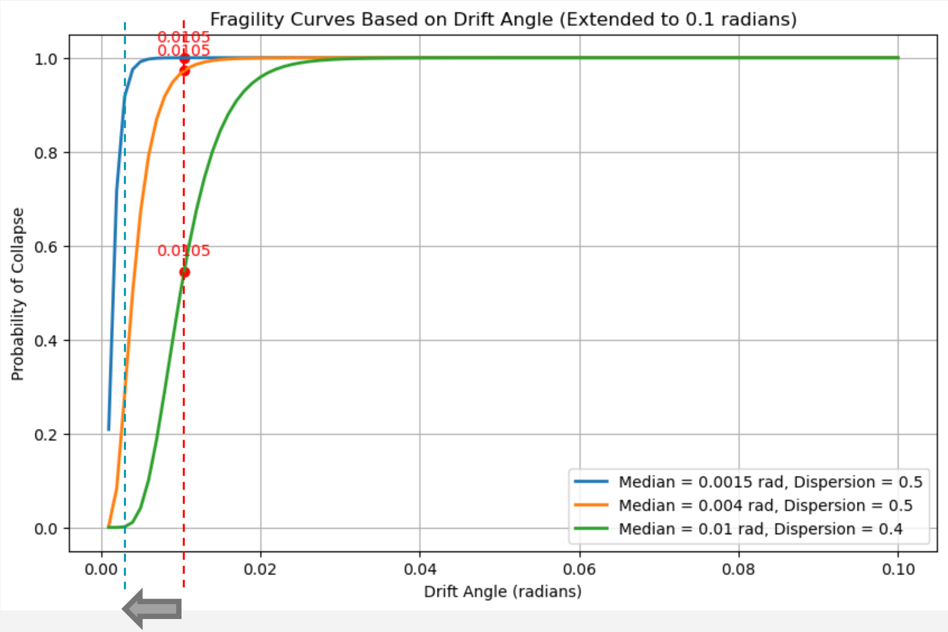
Thermal Recommendations

Blocks with better thermal properties



Increase external shading

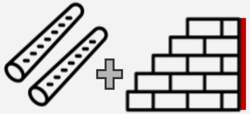
Seismic Recommendations



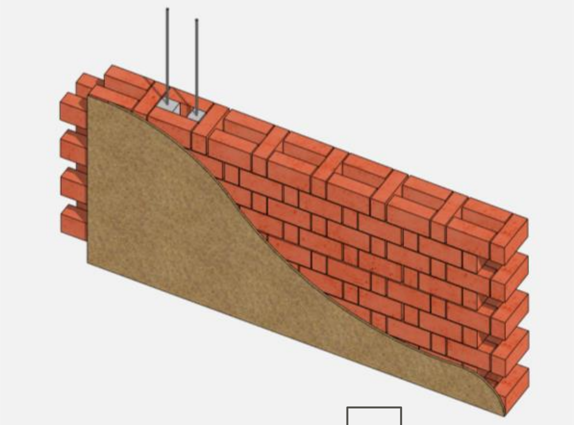
To improve the seismic performance, the value of drift angles should decrease or improving the fragility curves by moving them towards the positive x direction

Seismic Recommendations

Based on this prediction, the script provided the following recommendations to improve Seismic resilience as per Indian Standard Earthquake Resistant Design and Construction of Buildings Code of Practice (IS 4326: 1993)



Min 10mm Reinforcing bars embedded in brick masonry

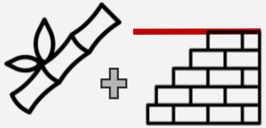


```
Please enter the following parameters for drift angle prediction:
Enter Length: 4
Enter Width: 4
Enter Total Height: 3.35
Enter Magnitude of Earthquake: 5.5
Enter Section Size: 0.35

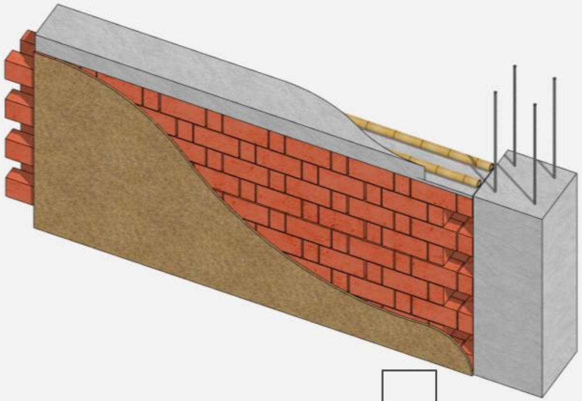
Predicted Drift Angle: 0.0105
```

Seismic Recommendations

Based on this prediction, the script provided the following recommendations to improve Seismic resilience as per Indian Standard Earthquake Resistant Design and Construction of Buildings Code of Practice (IS 4326: 1993)



Horizontal seismic bands with bamboo reinforcement



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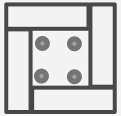
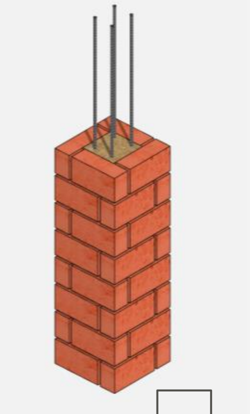


2 brick thick rat trap bonded wall with corner reinforcement



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Seismic Recommendations

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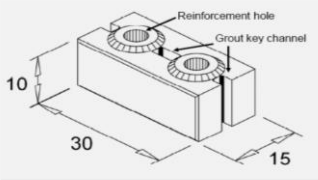
```



Hollow interlocking CSEB block wall

Ferro cement roofing, 60% lighter

Conclusion and takeaways

"How can machine learning techniques be effectively applied to optimize the workflow of seismic and heat waves resilience analysis in building facades?"

- By Implementing supervised and unsupervised machine learning architectures
- By giving results for both hazards on the same platform
- By finding hidden relationships among different features
- By providing a detailed feature importance chart
- By continuously learning on the data provided

Conclusion and takeaways

Thermal

TMY for the hottest year
Hazard

Fragility curve not known
Fragility

Spatial thermal autonomy
Demand parameter

Exceeding SET limit
Damage

Recommendations
Repair

Resilience and economic loss unknown
Resilience

Seismic

Earthquake magnitude
Hazard

Fragility curve
Fragility

Inter-story Drift angles
Demand parameter

Damage State
Damage

Repair time and cost
Recovery

Resilience and economic loss
Resilience

Future Research

- Expanding the reach of the project by conducting this research in different locations. Also more categorization in terms of comfort levels
- Enabling the model to predict for future scenario
- Providing new data for the ML model to predict for different archetypes
- Validating the costs used to calculate the economic loss in India
- Validating the figures used to calculate downtime in India
- Fragility functions for local façade construction
- Creating Hazard spectrum for earthquakes in India

Thank You!

Questions?

MSc Graduation Presentation on:

Enhancing Building Facade Resilience Analysis through Machine Learning

Optimizing Workflow for Seismic and Heat Wave Resilience Measures

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