Table of Contents

Supplementary Materials A – GEE Script 1

Supplementary Materials B: R Script 3

Supplementary Materials C: Architectural Morphology Documentation 6

Supplementary Materials D: Thermal comfort analysis of the documented houses 15

Supplementary Materials E: Thermal mass and thermal transmittance on building materials 19

Supplementary Materials A – GEE Script

```
/**********************************************************
 SUPPLEMENTARY MATERIALS A – GEE SCRIPT
 Multi-scale thermal analysis using Landsat 8 Collection 2 L2
**********************************************************/

// ---------------------------------------------------------
// 1. DEFINE STUDY AREA
// ---------------------------------------------------------
var studyArea = ee.Geometry.Rectangle([72.95, 26.20, 73.10, 26.35]);

// Historic zone polygon
var historic = ee.Geometry.Polygon([
  [[72.995,26.295],
   [73.020,26.295],
   [73.020,26.315],
   [72.995,26.315]]
]);

// Modern zone polygon
var modern = ee.Geometry.Polygon([
  [[73.050,26.250],
   [73.080,26.250],
   [73.080,26.280],
   [73.050,26.280]]
]);

// Transect line
var transect = ee.Geometry.LineString([
  [72.99,26.31],
  [73.08,26.26]
]);

Map.centerObject(studyArea, 12);

// ---------------------------------------------------------
// 2. LOAD LANDSAT 8 COLLECTION 2 LEVEL 2
// ---------------------------------------------------------
var startDate = '2018-05-01';
var endDate   = '2023-06-30';

var landsat = ee.ImageCollection('LANDSAT/LC08/C02/T1_L2')
  .filterDate(startDate, endDate)
```

```
  .filterBounds(studyArea)
  .filter(ee.Filter.lt('CLOUD_COVER', 20));

// ------------------------------------------------------------
// 3. APPLY SCALE FACTORS
// ------------------------------------------------------------
function applyScaleFactors(image) {

  var opticalBands = image.select('SR_B.*')
      .multiply(0.0000275)
      .add(-0.2);

  var thermalBand = image.select('ST_B10')
      .multiply(0.00341802)
      .add(149.0)
      .rename('LST_K');

  return image.addBands(opticalBands, null, true)
              .addBands(thermalBand, null, true);
}

var landsatScaled = landsat.map(applyScaleFactors);

// ------------------------------------------------------------
// 4. CREATE MEAN COMPOSITE
// ------------------------------------------------------------
var composite = landsatScaled.mean();

var LST_C = composite.select('LST_K')
    .subtract(273.15)
    .rename('LST_C');

var NDVI = composite.normalizedDifference(['SR_B5','SR_B4'])
    .rename('NDVI');

var NDBI = composite.normalizedDifference(['SR_B6','SR_B5'])
    .rename('NDBI');

var stack = LST_C.addBands(NDVI).addBands(NDBI);

// ------------------------------------------------------------
// 5. ZONAL STATISTICS
// ------------------------------------------------------------
function zonalStats(region, name){
  var stats = LST_C.reduceRegion({
    reducer: ee.Reducer.mean()
      .combine(ee.Reducer.stdDev(), '', true)
      .combine(ee.Reducer.count(), '', true),
    geometry: region,
    scale: 30,
    maxPixels: 1e9
  });

  return ee.Feature(null, stats).set('Zone', name);
}

var historicStats = zonalStats(historic, 'Historic');
var modernStats   = zonalStats(modern, 'Modern');

var zonalTable = ee.FeatureCollection([historicStats, modernStats]);
```

```
Export.table.toDrive({
  collection: zonalTable,
  description: 'Zonal_LST_Statistics',
  fileFormat: 'CSV'
});

// ------------------------------------------------------------
// 6. RANDOM PIXEL SAMPLING (n = 8000)
// ------------------------------------------------------------
var samples = stack.sample({
  region: studyArea,
  scale: 30,
  numPixels: 8000,
  seed: 42,
  geometries: false
});

Export.table.toDrive({
  collection: samples,
  description: 'LST_NDVI_NDBI_Samples',
  fileFormat: 'CSV'
});

// ------------------------------------------------------------
// 7. TRANSECT EXTRACTION
// ------------------------------------------------------------
var transectSamples = LST_C.sample({
  region: transect,
  scale: 30,
  geometries: true
});

Export.table.toDrive({
  collection: transectSamples,
  description: 'LST_Transect_Profile',
  fileFormat: 'CSV'
});
```

Supplementary Materials B: R Script

```
############################################################
# SUPPLEMENTARY MATERIALS B – R SCRIPT
# Thermal Regression and Figure Generation
############################################################

library(tidyverse)
library(ggplot2)
library(broom)
library(cowplot)

setwd("/Volumes/Jeevan/Jodhpur/data")

zonal <- read.csv("Zonal_LST_Statistics.csv")
samples <- read.csv("LST_NDVI_NDBI_Samples.csv")
transect <- read.csv("LST_Transect_Profile.csv")

############################################################
# 1. ZONAL DIFFERENCE
```

```
############################################################

fig_zonal <- ggplot(zonal, aes(x = Zone, y = LST_C_mean, fill = Zone)) +
  geom_col(width = 0.6, color = "black") +
  geom_errorbar(aes(ymin = LST_C_mean - LST_C_stdDev,
                    ymax = LST_C_mean + LST_C_stdDev),
                width = 0.2, linewidth = 0.8) +
  coord_cartesian(ylim = c(35, 41)) +
  theme_classic(base_size = 13) +
  theme(legend.position = "none")

ggsave("Fig_Zonal.png", fig_zonal, width = 6.5, height = 5, dpi = 600)

############################################################
# 2. SIMPLE REGRESSION MODELS
############################################################

model_n <- lm(LST_C ~ NDBI, data = samples)
model_v <- lm(LST_C ~ NDVI, data = samples)
model_full <- lm(LST_C ~ NDVI + NDBI, data = samples)

write.csv(tidy(model_n), "Regression_NDBI.csv", row.names = FALSE)
write.csv(tidy(model_v), "Regression_NDVI.csv", row.names = FALSE)
write.csv(tidy(model_full), "Regression_Full.csv", row.names = FALSE)

############################################################
# 3. NDBI REGRESSION PLOT
############################################################

r2 <- summary(model_n)$r.squared

fig_ndbi <- ggplot(samples, aes(x = NDBI, y = LST_C)) +
  geom_point(alpha = 0.18, size = 0.6, color = "#7A0019") +
  geom_smooth(method = "lm", color = "black", linewidth = 1) +
  annotate("text",
           x = min(samples$NDBI)+0.02,
           y = max(samples$LST_C)-0.5,
           label = paste0("R² = ", round(r2,3), "\np < 0.001"),
           hjust = 0, size = 5) +
  theme_classic(base_size = 13)

ggsave("Fig_NDBI.png", fig_ndbi, width = 7, height = 5, dpi = 600)

############################################################
# 4. TRANSECT ANALYSIS
############################################################

transect$distance <- seq(0, nrow(transect)-1) * 30
deltaT <- max(transect$LST_C) - min(transect$LST_C)

fig_transect <- ggplot(transect, aes(x = distance, y = LST_C)) +
  geom_line(alpha = 0.4, color = "#7A0019") +
  geom_smooth(span = 0.12, se = FALSE, color = "black") +
  annotate("text",
           x = max(transect$distance)*0.05,
           y = max(transect$LST_C),
           label = paste0("ΔT ≈ ", round(deltaT,2), "°C"),
           hjust = 0) +
  theme_classic(base_size = 13)

ggsave("Fig_Transect.png", fig_transect, width = 8, height = 5, dpi = 600)
```

```
############################################################
# 5. STANDARDIZED COEFFICIENTS
############################################################

samples_std <- samples
samples_std$LST_C <- scale(samples$LST_C)
samples_std$NDBI  <- scale(samples$NDBI)
samples_std$NDVI  <- scale(samples$NDVI)

model_std <- lm(LST_C ~ NDBI + NDVI, data = samples_std)
coef_df <- tidy(model_std)
coef_df <- coef_df[coef_df$term != "(Intercept)", ]

fig_coef <- ggplot(coef_df,
                   aes(x = term, y = estimate)) +
  geom_col(fill = "#4B2C83", width = 0.6) +
  geom_errorbar(aes(ymin = estimate - std.error,
                    ymax = estimate + std.error),
                width = 0.2,
                linewidth = 0.8) +
  theme_classic(base_size = 13)

ggsave("Fig_Standardized.png", fig_coef,
       width = 6, height = 5, dpi = 600)
```

Supplementary Materials C: Architectural Morphology Documentation

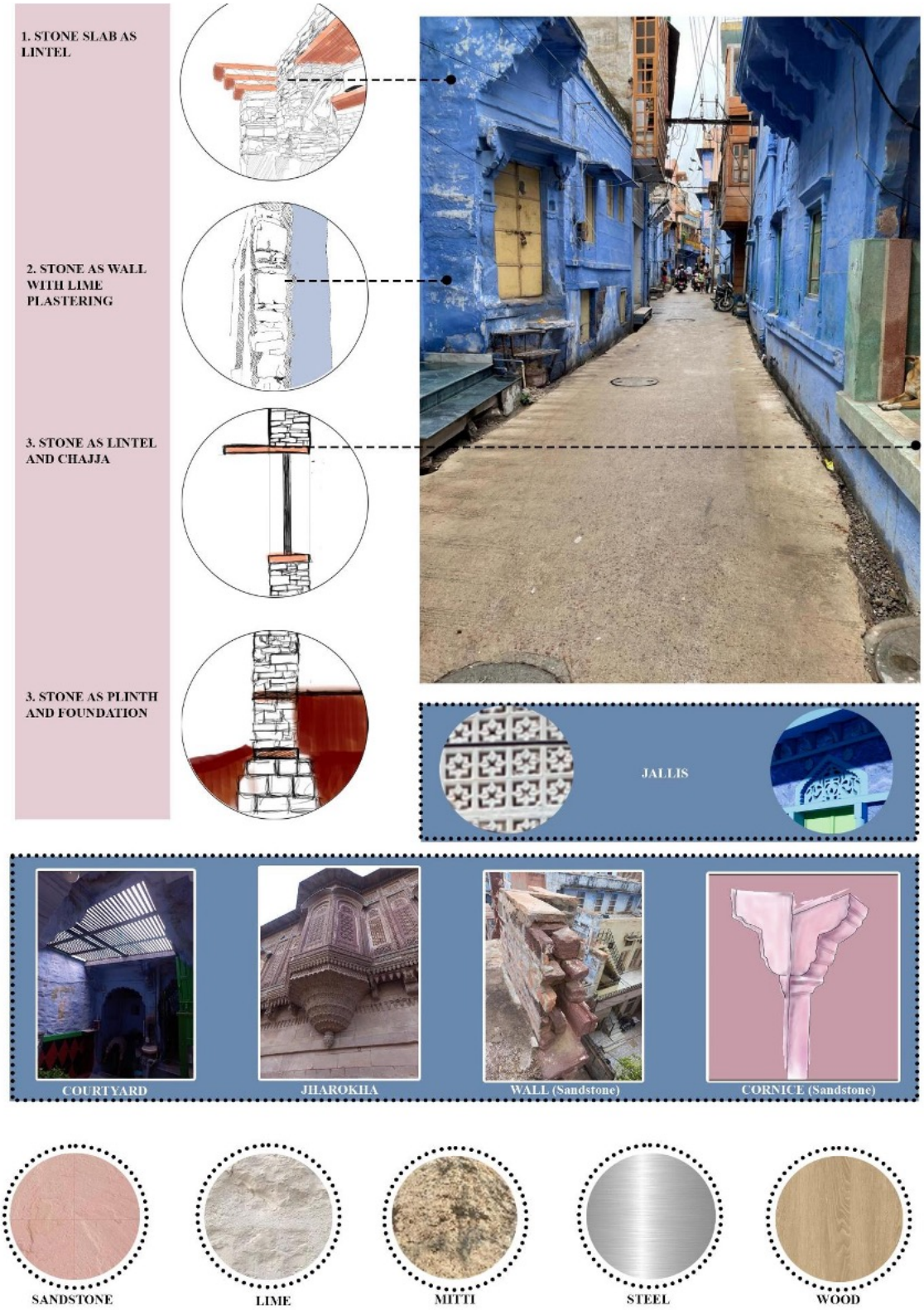


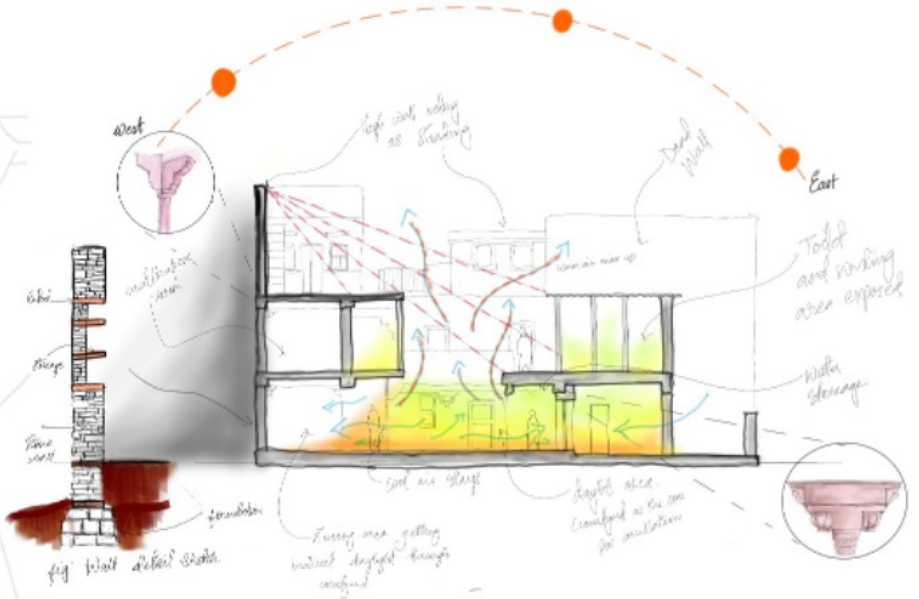
Figure S1. Pictorial representation of the building materials and techniques

DOCUMENTATION: Traditional House of Jodhpur

HOUSE - 1
INTRODUCTION

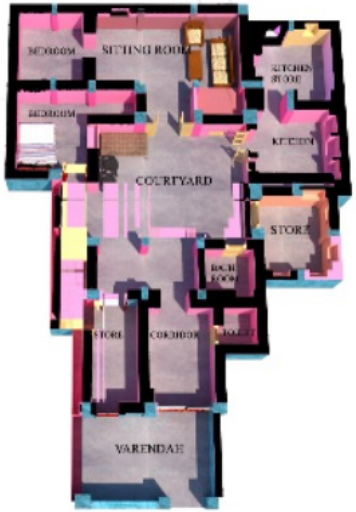
LOCATION : JODHPUR, RAJASTHAN
26.17 deg N, 73.01 deg E
AGE : 450 YEARS
STRUCTURE : STONE AS PRIMARY MATERIAL

"I am Yashwant Singhvi and I stay in this house with my son, daughter-in-law and two grand-daughters. I am proud that I own this house which is almost 450 years old, as old as the Mehrangarh Fort. I was told several stories of how this house was built from scratch by workmen using just their hands and no machines, as it is done today. Of course, we had to make some modifications to the house depending on the modern day necessities, but we have tried to keep most of the elements as it were. You won't believe the daily life we used to have earlier, which revolved around everything that was nearby; from gathering water from the nearby water-bodies (step-well, well) to grinding flour. I miss those days and those ways of life sometime!"





FIRST FLOOR



GROUND FLOOR

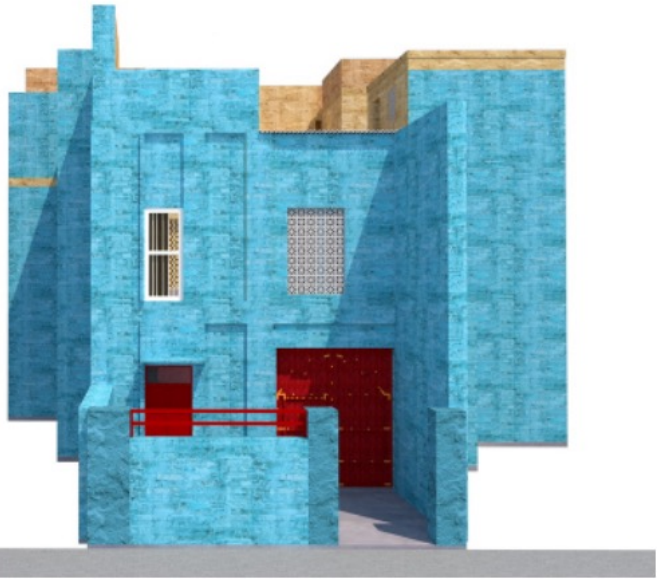


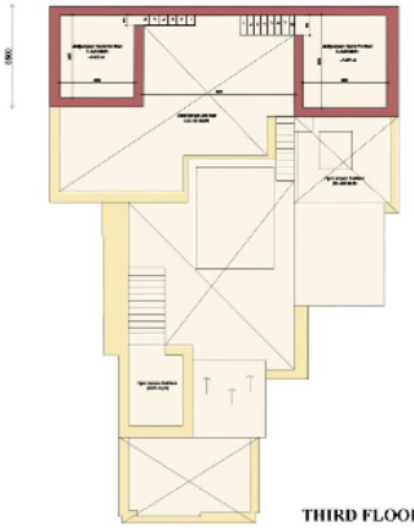
Figure S2. Architectural Documentation and analysis of traditional houses



Figure S3. Architectural Documentation and analysis of traditional houses



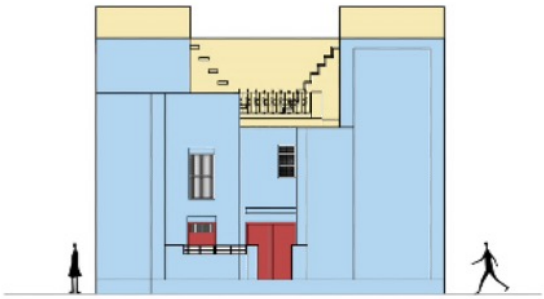
SECOND FLOOR



THIRD FLOOR

N

ELEVATION





SITTING AREA (COURTYARD)



CORNICE



LIVING ROOM



TYPICAL ROMM



COURTYARD WITH ENTRANCE CORRIDOR



CORNICE

Figure S4. Architectural Documentation and analysis of traditional houses

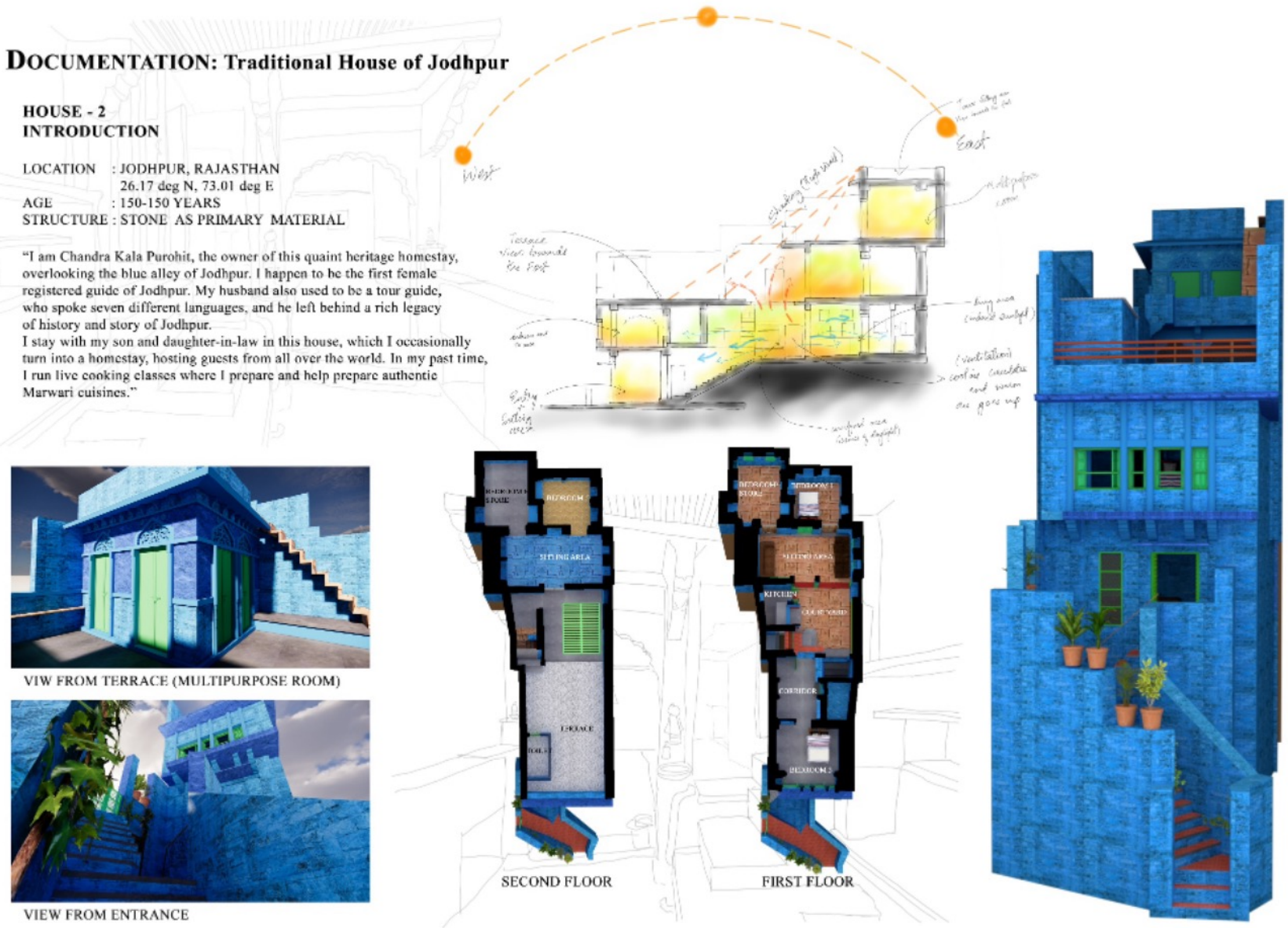


Figure S5. Architectural Documentation and analysis of traditional houses

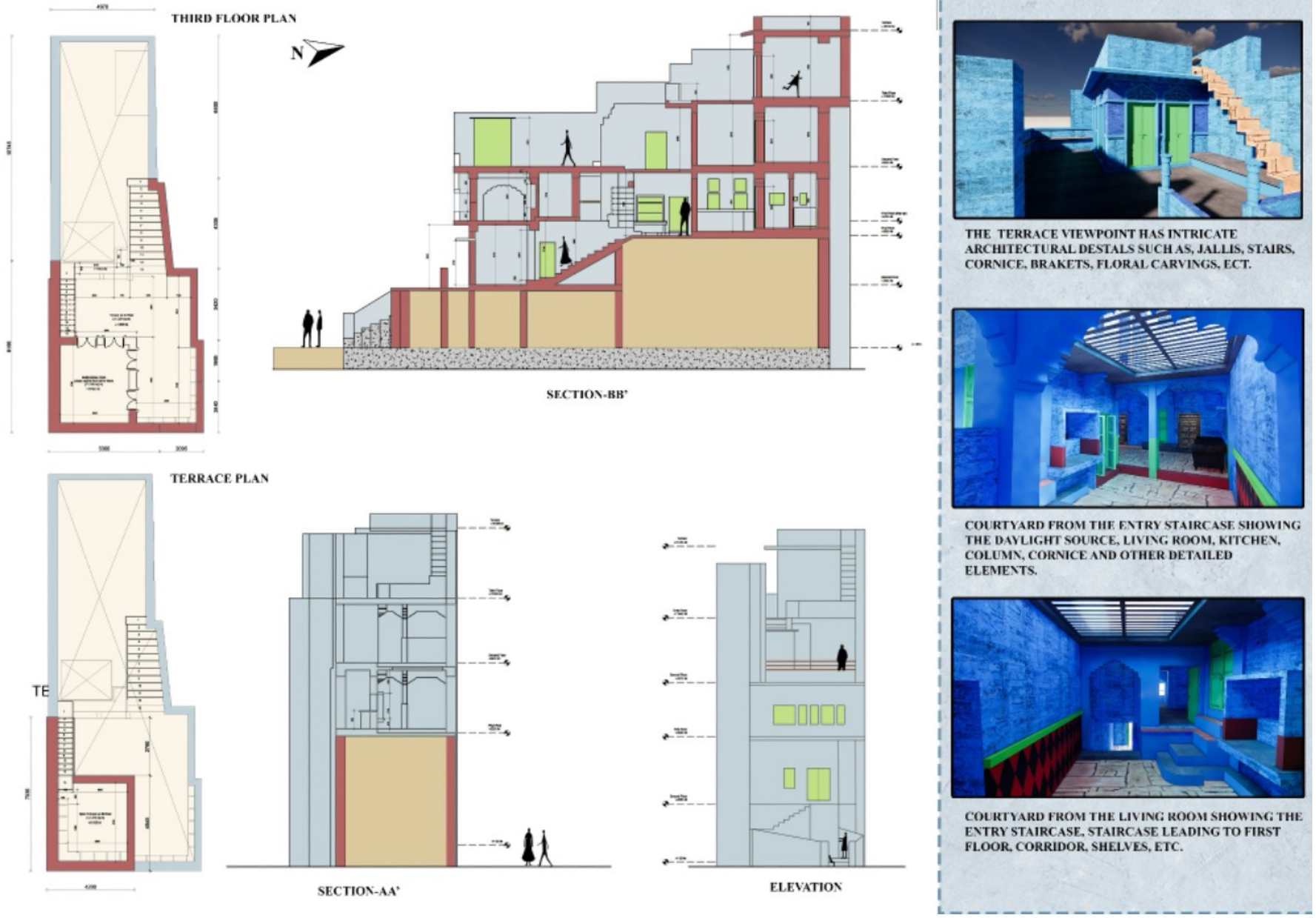
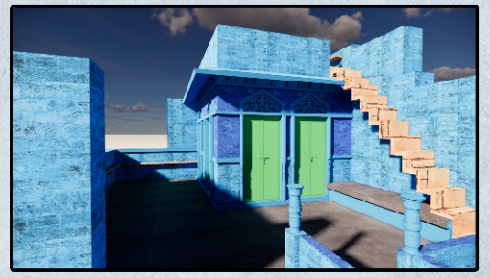


Figure S6. Architectural Documentation and analysis of traditional houses





THE TERRACE VIEWPOINT HAS INTRICATE ARCHITECTURAL DESTALS SUCH AS, JALLIS, STAIRS, CORNICE, BRAKETS, FLORAL CARVINGS, ECT.



COURTYARD FROM THE ENTRY STAIRCASE SHOWING THE DAYLIGHT SOURCE, LIVING ROOM, KITCHEN, COLUMN, CORNICE AND OTHER DETAILED ELEMENTS.



COURTYARD FROM THE LIVING ROOM SHOWING THE ENTRY STAIRCASE, STAIRCASE LEADING TO FIRST FLOOR, CORRIDOR, SHELVES, ETC.

Figure S7. Architectural Documentation and analysis of traditional houses

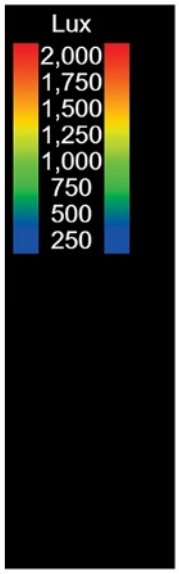
HOUSE - 1



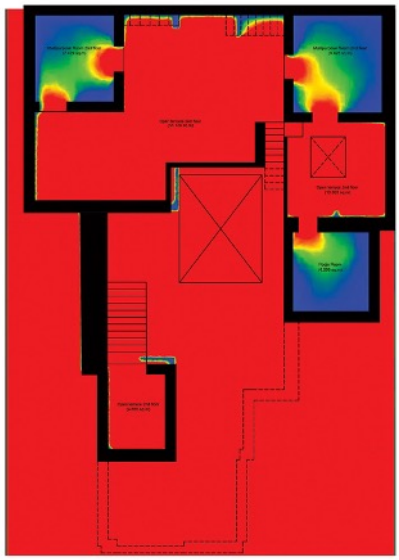
GROUND FLOOR



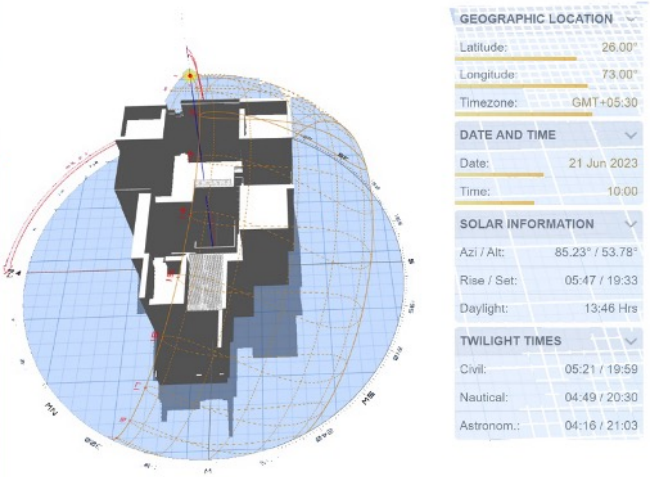
FIRST FLOOR



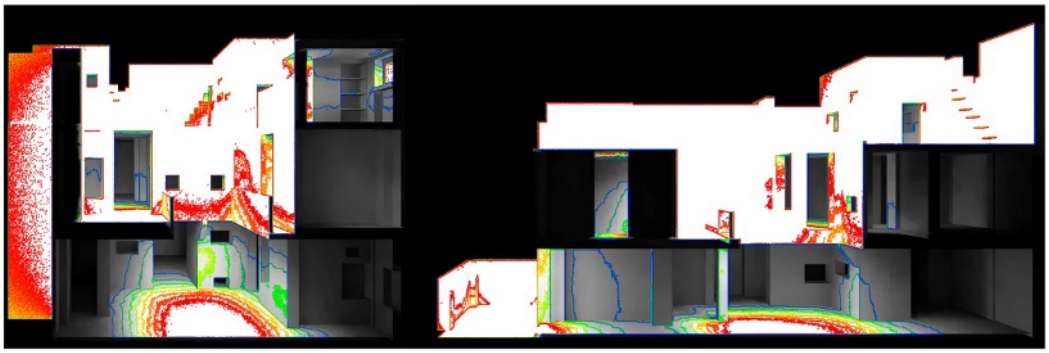
LUX LEVEL



SECOND FLOOR



SUMMER SOLSTICE (3D SUNPATH)



SECTION AT A-A

SECTION AT B-B

Figure S8. Daylighting analysis of the documented House 01

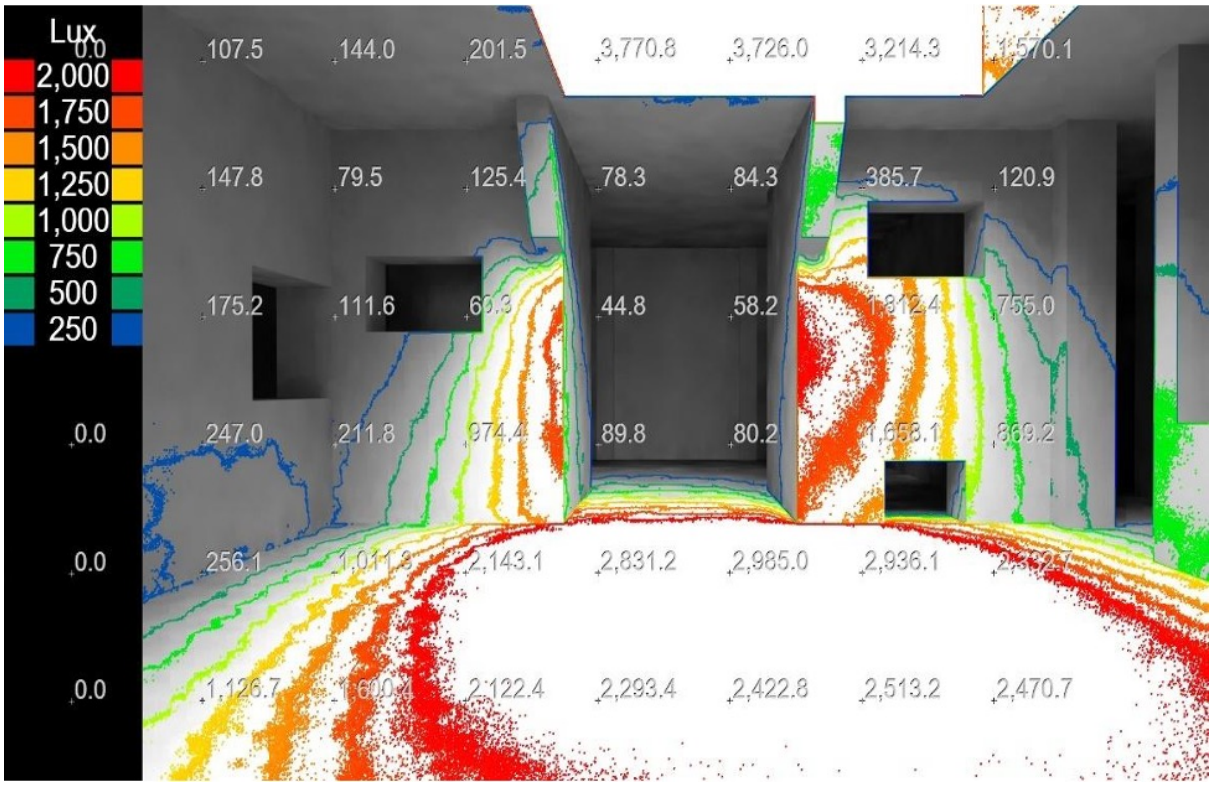


Figure S9. Courtyard House 01 (illuminance level at June 21st ,10am)

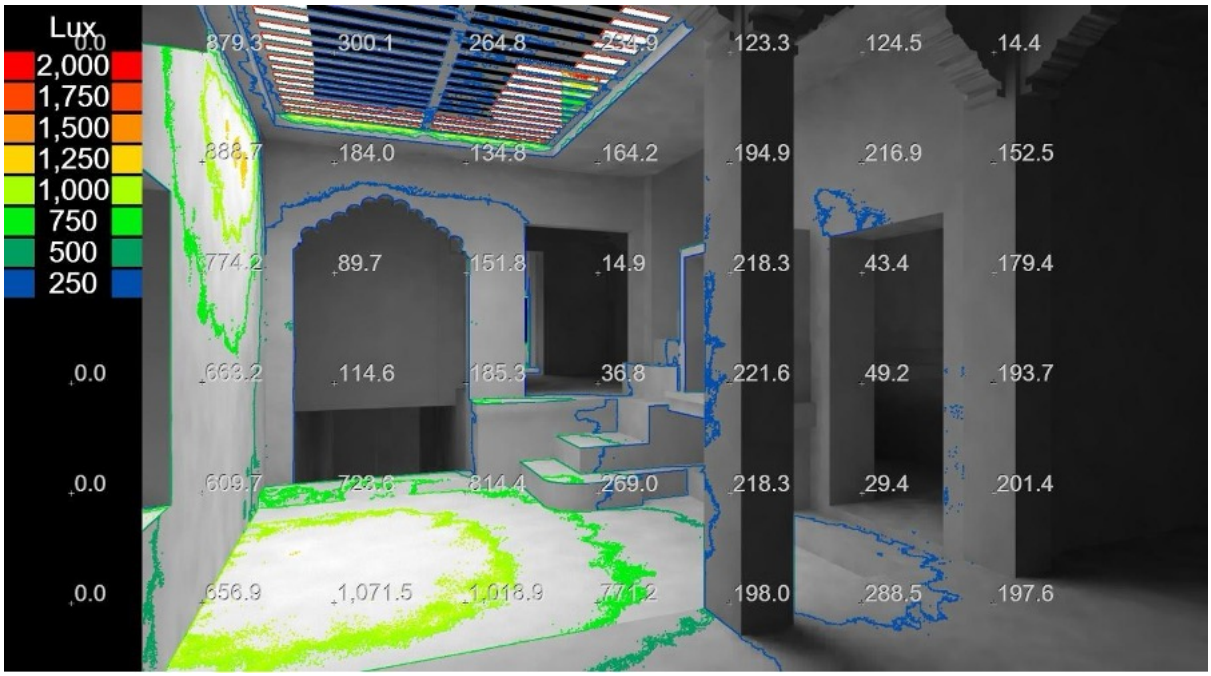


Figure S10. Courtyard House 02 (illuminance level at June 21st ,10am)

HOUSE - 2

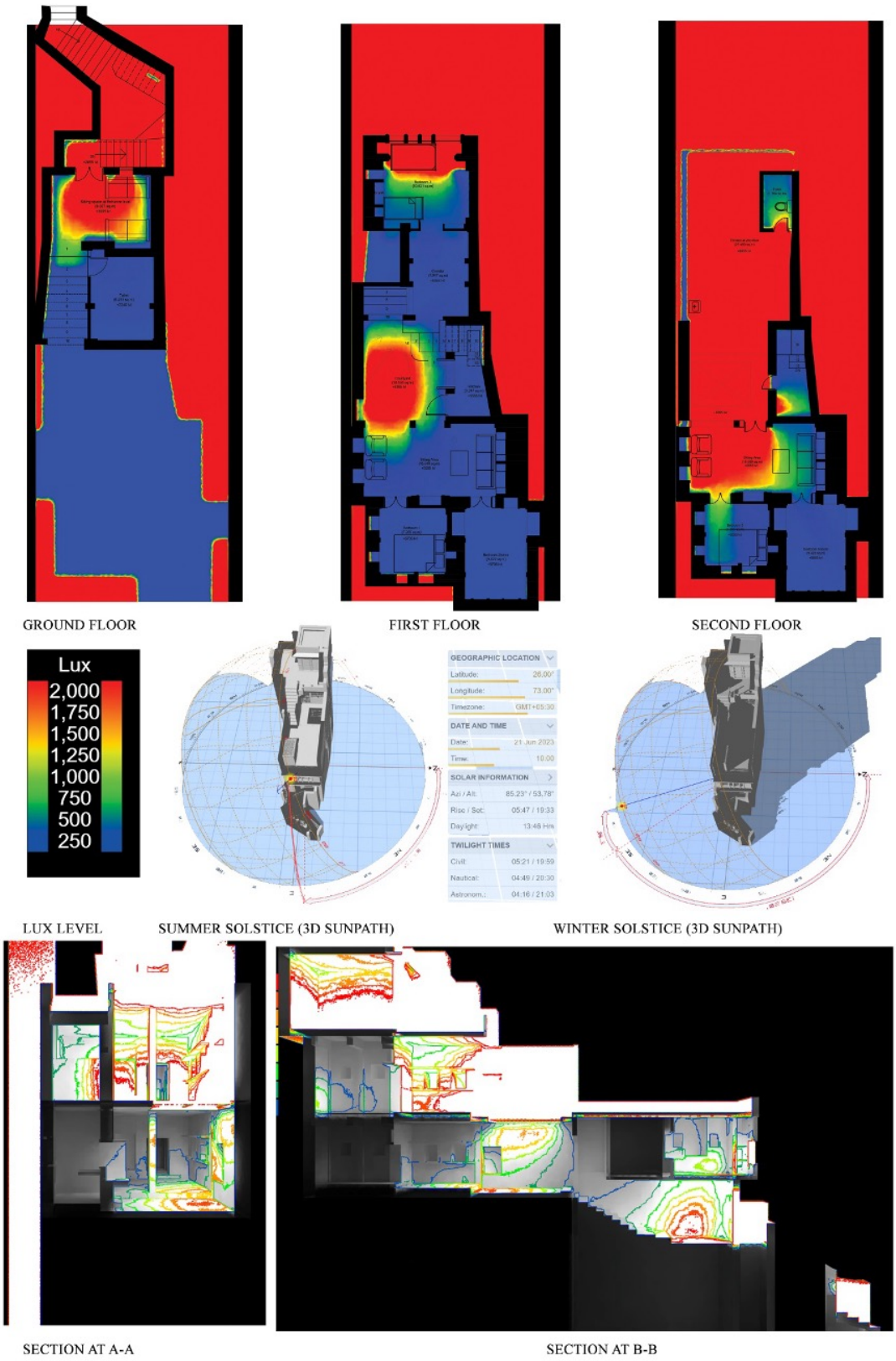


Figure S11. Daylighting analysis of the documented House 02

Supplementary Materials D: Thermal comfort analysis of the documented houses

The analysis is based on the evaluation of the questionnaire responses to the occupants of the documented house. Thermal comfort as per ASHRAE STANDARD 55 the comfort zone is considered to be sufficiently comfortable if at least 80% of its occupants can be expected not to object to the ambient conditions, meaning that the majority are between -0.5 and 0.5 on the PMV scale. The predicted mean vote (PMV) scale is a measurement scale used to assess human thermal comfort in an indoor environment that typically ranges from +3(hot) to -3(cold).

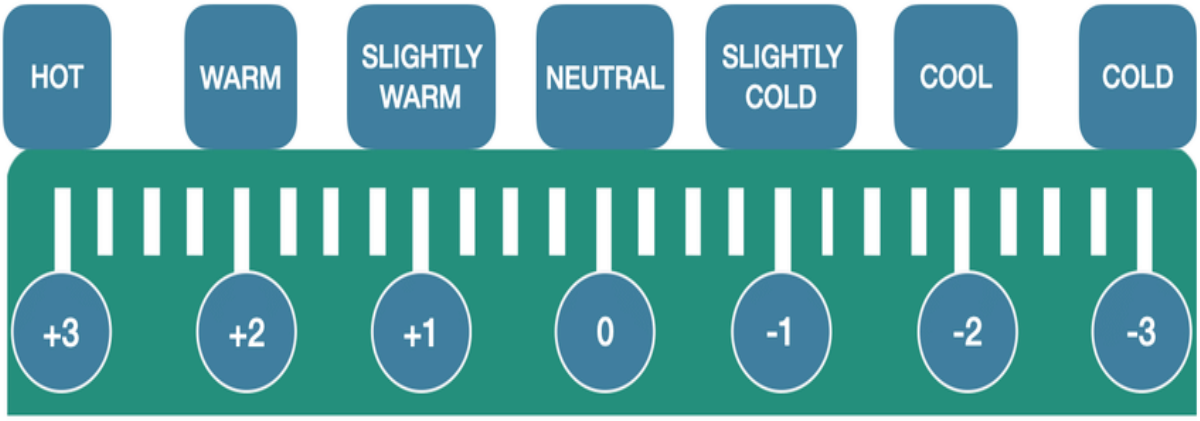


Figure S12. Graphical representation of the seven-point ASHRAE thermal sensation scale

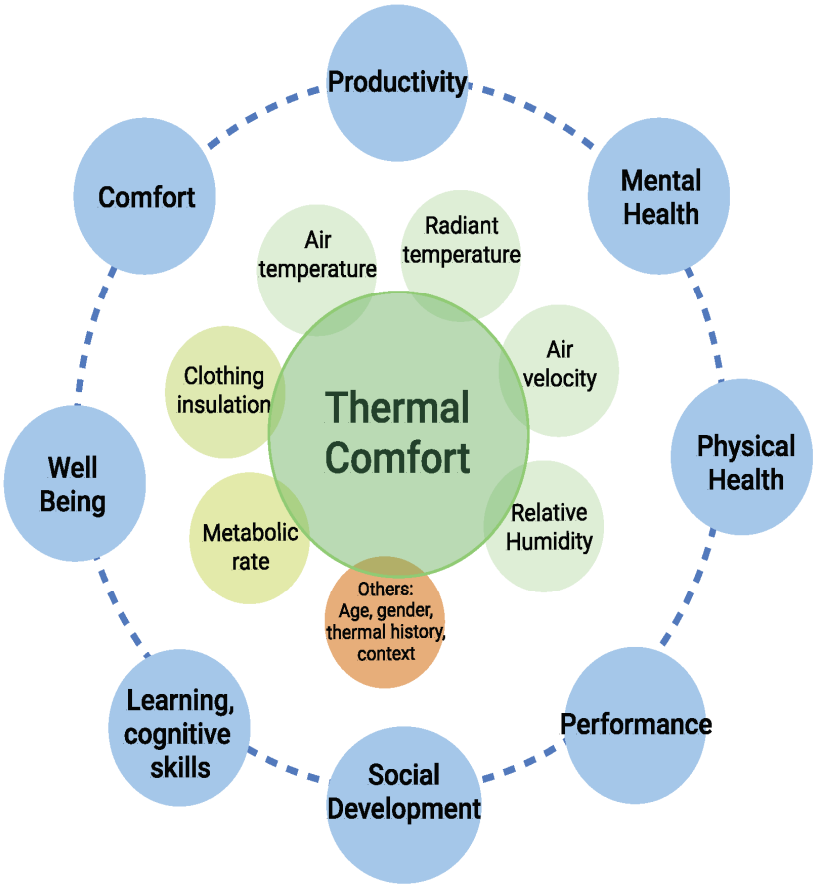
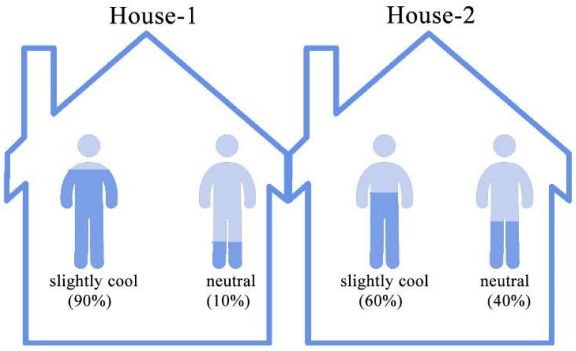
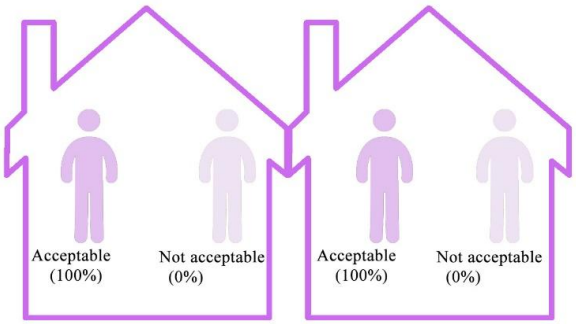


Figure S13. Thermal comfort and its effect

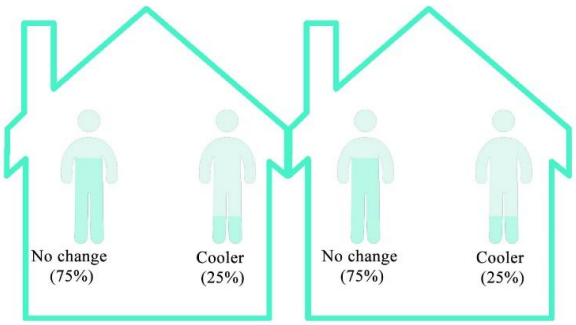
Thermal Comfort
In the Distribution of percentage on the subjective judgement on thermal comfort.
Residents were asked their thermal comfort level on PMV scale.



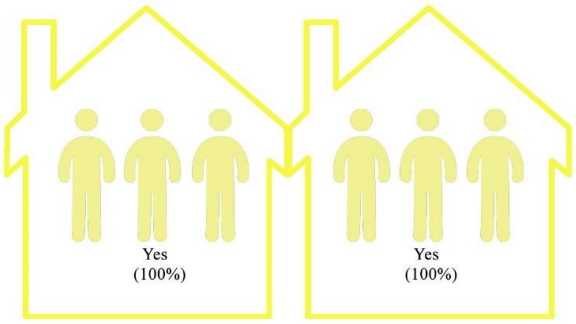
Thermal Acceptability
In the Distribution of percentage on the subjective judgement on thermal acceptablity.
Residents were asked rate to on the overall indoor environment.
.



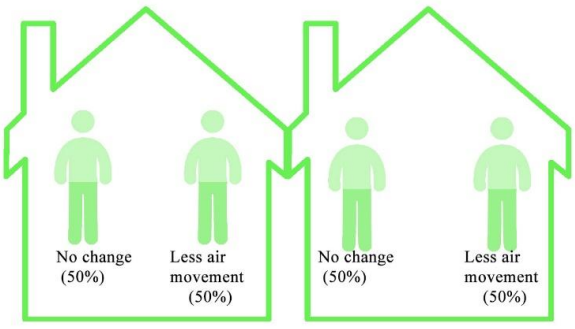
Thermal Preference
In the Distribution of percentage on the subjective judgement on thermal preference.
Residents were asked their thermal preference.



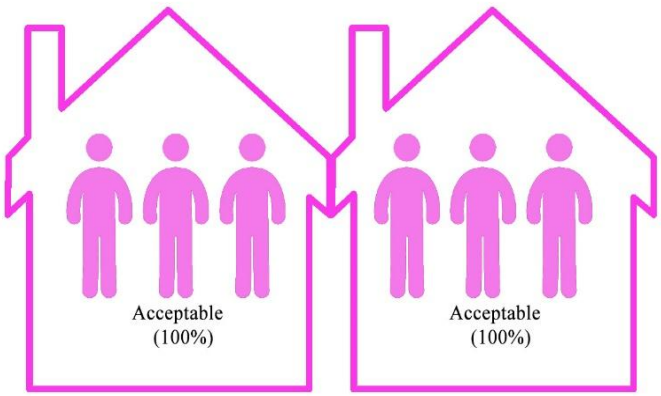
Satisfaction of Thermal Environment
In the Distribution of percentage on the subjective judgement on Satisfaction of Thermal Environment
Residents were asked their satisfation of thermal environment.



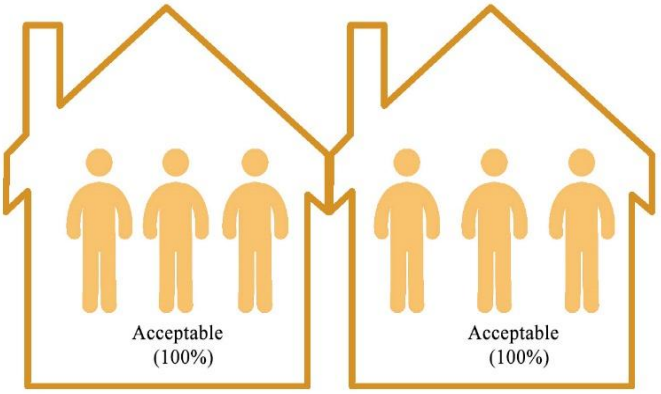
Air movement preference
In the Distribution of percentage on the subjective judgement on Air movement preference
Residents were asked their preference of air movement.



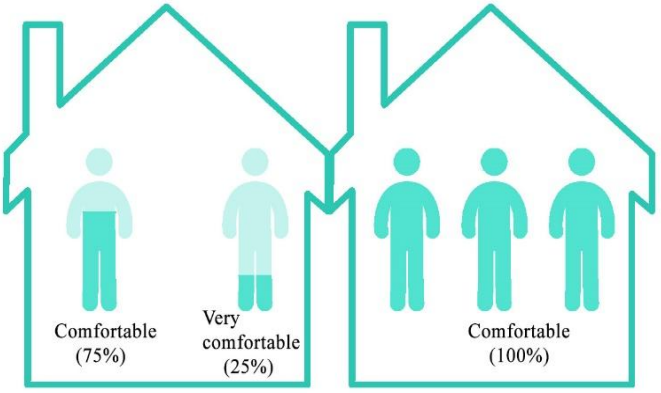
Acceptability of Air movement
In the Distribution of percentage on the subjective judgement on Acceptability of Air movement
Residents were asked their Acceptability of Air movement
.



Acceptability of Humidity
In the Distribution of percentage on the subjective judgement on Acceptability of Humidity
Residents were asked their Acceptability of Humidity



Humidity Preference
In the Distribution of percentage on the subjective judgement on Humidity Preference
Residents were asked their preference of humidity.



General Comfort
In the Distribution of percentage on the subjective judgement on General Comfort
Residents were asked comfortability.

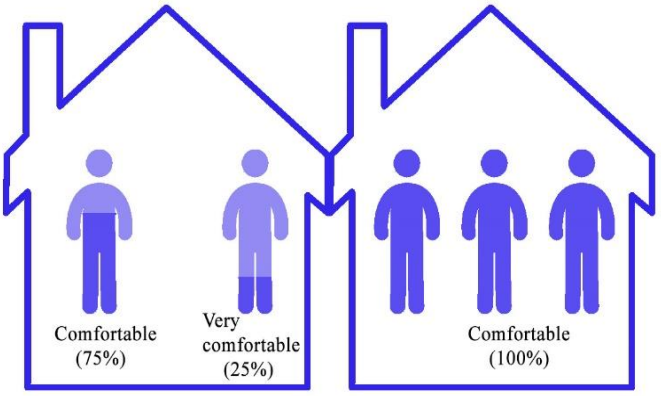


Figure S14. Thermal comfort analysis

Supplementary Materials E: Thermal mass and thermal transmittance on building materials

Thermal mass refers to the ability of the materials to store heat. Materials with high thermal have the capacity to absorb, store, and release heat energy when subjected to temperature variations. The thermal storage ability of the material here is analysed by the thermal transmittance (u-value) which is the rate of transfer of heat through stone and brick and the time delay due to the thermal mass known as time lag (Φ).

Stone is the primary construction material in Jodhpur with the wall thickness varying from 350mm to 500mm. In traditional buildings, sandstone is used for walls, columns, slabs, lintels, flooring, and other architectural elements. It provides structural stability and regulates the indoor temperature. Chittar/Sandstone of Jodhpur exists in different colours such as red, pink, brown, greenish, yellow and grey. From the old settlement to the new settlement, sandstone has been used in different forms ranging from building materials to interior and exterior decoration and handicrafts. Sandstones have a different level of porosity, compressive strength, and hardness with a water absorption of 1.25% and compressive strength of 390 Kg/cm^3.

Brick, as construction materials start from clay bricks to mechanised bricks has a wide variety based on the manufacturer. It is easily available and the most common building material in the region, it is famous for its distinctive and diverse range of clay bricks. the region is known for producing bricks in various colours, including red, brown and brown. Clay bricks are the hallmark of Rajasthani architecture, it is found in heritage structures like forts, palaces, and havelis with an intricate finish. Clay brick is considered a sustainable building material for its cost-effectiveness and thermal insulating properties.

Table S1. u-value calculation

u-value for solid wall made of stone				
SI.No	Material	Thickness (mm)	Thermal Conductivity (w/mk)	Thermal Resistance (m^2k/w)
1	Ext. Surface			0.04
2	Stone Wall	0.4	2.3	0.92
3	Int. Surface			0.13
	R_t			1.09
	U			0.917431
u - value for solid wall made of brick				
SI.No	Material	Thickness (mm)	Thermal Conductivity (w/mk)	Thermal Resistance (m^2k/w)
1	Ext. Surface			0.04
2	Brick wall	0.23	0.84	0.1932
3	Int. Surface			0.13
	R_t			0.3632
	U			2.753304

The above table shows the u-value (Thermal transmittance) comparison of the traditional building of a stone wall with a thickness of 450mm, and the modern building of a brick wall with a thickness of 230mm. From the above calculations of different wall types, we can conclude that the traditional building has a much lower U-value meaning that it has better insulating performance than the modern brick wall. The lower the U-value the better the insulating performance.