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Executive Summary

Demonstration of impact of cool roof on improving thermal comfort in affordable housing in Andhra Pradesh

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EXECUTIVE SUMMARY

Demonstration of impact of cool roof on improving thermal comfort in affordable housing in Andhra Pradesh

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Summary Prepared by

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The Summary Report is extracted from the Field Monitoring Study Report submitted to BEEP by the Administrative Staff College of India (ASCI). The Field Monitoring Study Report was prepared by the following ASCI team:

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1. Background

The state government of Andhra Pradesh (AP) is supporting construction of 30 lakh houses for the economically weaker section of society. This programme is a part of the government's 'Housing for all poor' under Navaratnalu (Nine's scheme's). The project comes under Beneficiary Led Construction or Enhancement (BLC), which is one of the four components under Pradhan Mantri Awas Yojana (Urban). Andhra Pradesh State Housing Corporations Ltd (APSHCL) is the state nodal agency for PMAY(U) in AP.

APSHCL is interested in integrating the provision of *Eco-Niwas Samhita (ENS)* in the project to ensure thermally comfortable and energy efficient houses. Indo-Swiss Building Energy Efficiency Project (BEEP) and the Andhra Pradesh State Energy Conservation Mission (APSECM), along with BEEP's local partner Administrative Staff College of India (ASCI), have provided technical support to APSHCL in integrating energy efficient and thermally comfortable (EETC) measures in this project.

- During 2020, a simulation-based technical analysis report was prepared for a typical affordable housing design on improving energy efficiency and thermal comfort, as well as meeting the Eco Niwas Samhita 2018 compliance. Increasing reflectivity of roof and improved natural ventilation were the key recommendations from the building energy simulation study. Natural ventilation was improved by providing additional openings. Some of the solutions to improve the reflectivity of roof were use of Reflective Paint, Reflective Tiles, and China Mosaic Finish.
- During 2021, BEEP, in association with ASCI, has conducted 12 training programmes for capacity building on EETC measures and ENS compliance. The training programme was for the APSHCL site engineers who are supervising the construction of houses under this programme. Furthermore, the Andhra Pradesh State Energy Efficiency Development Corporation Ltd (APSEEDCO) with the support of APSHCL had extended the programme with 13 additional training programmes covering all districts in the state.

Towards the end of 2021, APSECM and APSHCL showed an interest to take the work done in the past two years forward by implementing it on the ground and developing demonstrating projects in a few districts. The demo projects include adoption of improved reflectivity of roof (cool roof) in houses.

2. Study Objectives

The work has two broad objectives:

1. To showcase the impact of Cool Roof adoption through field monitoring study on improving thermal comfort in affordable housing in Andhra Pradesh.
2. To prepare ready reckoner and conduct dissemination programmes. The ready reckoner includes details of cool roof materials, available manufacturers/suppliers, cost of the materials and its application process.

3. Selection of houses and locations

After conducting the round-table meetings among APSHCL, APSECM, BEEP, and ASCI and doing several site visits, the impact assessment study locations were finalized. The three locations finalized were:

(A) Vellanki, Visakhapatnam

(B) Samalkot, Kakinada

(C) Vellatur, Bapatla

All three locations are in the warm-humid climate zone. A total of 12 houses were selected with 4 houses in each location. The houses were selected based on similar construction and orientation, shading obstacle, material, ready-to-occupy stage and

window-door positioning. Also, a combination of houses with false ceiling and without false ceiling were selected for diversity of results.

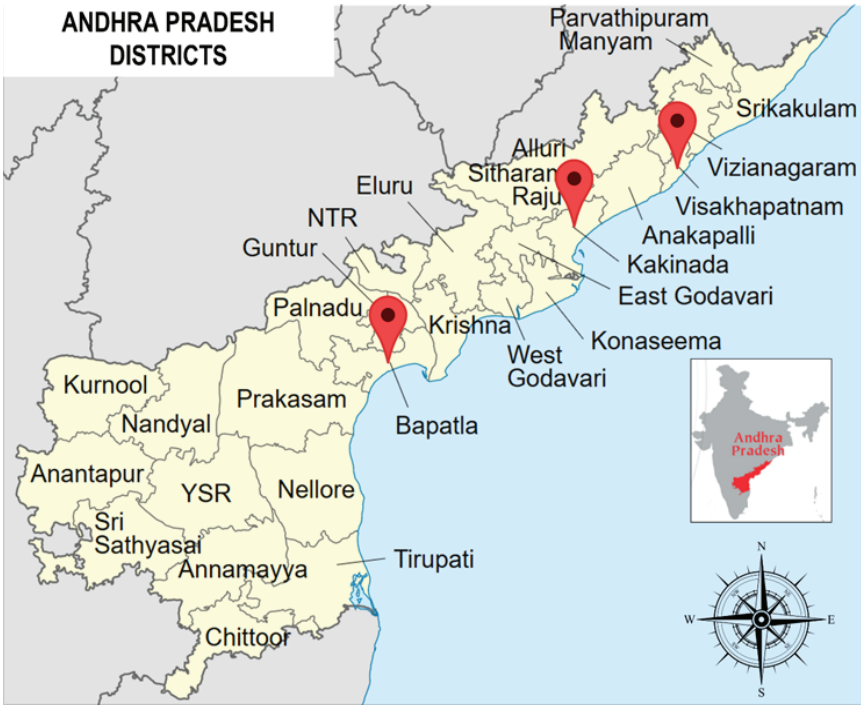

Figure 1. District map of Andhra Pradesh, shows the location of study (encircled)

The cool roof paint is used as the cool roof adoption strategy for demonstrating thermal comfort in affordable houses. Cool roof paint is used as it is one of the most economical and effective solutions available widely in the market. The cool roof paint has high reflectivity and emissivity, which helps in reflecting large part of solar radiation and thereby, minimizing heat absorption. Further, higher emissivity helps in emitting the absorbed heat during the night-time. Table 1 shows the details of selected houses.

Table 1. List of houses selected for demonstration

House no.	Site/Location	False Ceiling (Yes/No)	Cool Roof Applied (Yes/No)
1	Vellanki, Visakhapatnam	Yes	Yes
2		Yes	No
3		Yes	Yes
4		Yes	No
5	Samalkot, Kakinada	No	No
6		No	Yes
7		Yes	No
8		Yes	Yes
9	Vellatur, Bapatla	No	No
10		No	Yes
11		No	No
12		No	Yes

3.1 Applying cool roof

- The cool roof paint has 5 coats in total. The method to apply cool roof is as follows:
- The application process of cool roof paint begins with surface preparation, which ensures thoroughly washed clean, dirt-free, even surface.
- It proceeds with application of 2 coats of base layer, which is the mix of coating powder and water. The base layer is allowed to dry for a minimum of 2 hours between each layer.
- In the next step the 2 coats of ready-to-use reflective paint are applied with a sufficient drying time of 2–3 hours (in between each coating).
- The final reflective coat is applied on the dried surface for complete sealing.

The properties of cool roof paint are:

- SRI value: 109
- Reflectivity: 0.87
- Emissivity: 0.86

Figure 2. Five layers of coatings were applied on roof of selected houses.

4. Monitoring methodology

The four selected houses in each district are prepared for the monitoring. The preparation includes:

A) Two houses are coated with cool roof paint and the rest two houses are uncoated.

B) An onsite survey was conducted to determine characteristics of the houses (including areas of windows and doors, construction type, usage pattern, i.e., window opening and closing)

Figures 3–5 show the layout and site details of a typical house in a district..

Figure 3. Site layout with marked houses for monitoring (Image: Vellanki, Visakhapatnam)

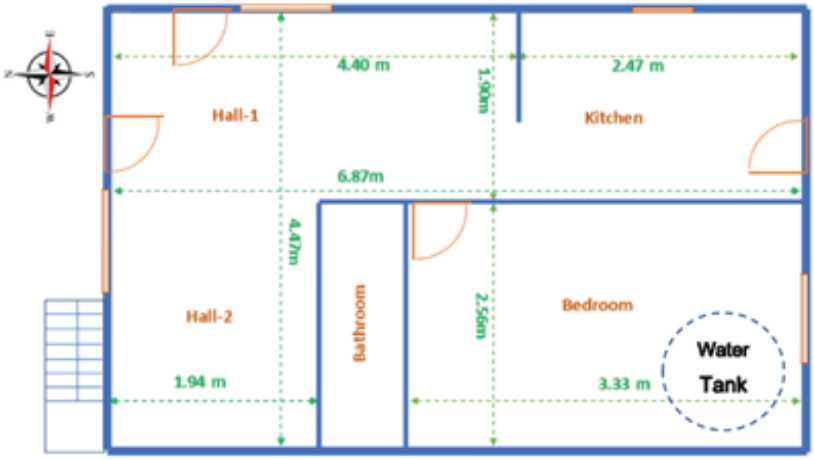

Figure 4. Layout of the typical monitoring houses

Figure 5. One of the monitored houses

A similar kind of preparation is done for other districts (in total 12 houses).

The parameters to measure for assessing the impact of cool roof are air temperature, relative humidity, surface temperature – under deck and over deck. The under-deck temperature is the inside surface ceiling temperature whereas over-deck temperature is the outside surface roof temperature.

A total of 12 sensors were installed per house – four under deck, four over deck, and four inside air temperature. The air temperature sensors were positioned at least 1.2 m away from the wall. The surface temperature sensors were positioned at four key locations of the roof and the ceiling. The location is specified in Figure 6. In addition, one sensor was placed outside in a shaded area to record ambient temperature and RH.

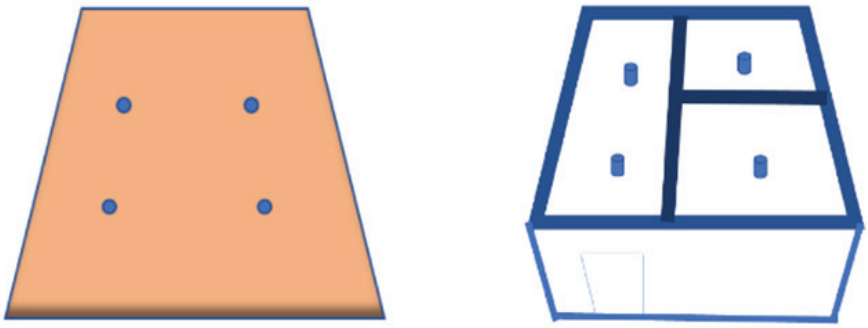

Figure 6. View of placement of instruments over the roof of a typical house

Table 2. Specifications of the instruments used for the monitoring

Instrument Name	Make	Parameter measured	Technical Specification	Picture	Type of measurement
Data logger	Customized by monitoring team	NA	Range -50 °C to 75 °C Resolution 0.01°C		Continuous logging at 5 minutes frequency
Ambient temperature and relative humidity sensor with data logging capability	Elitech	Air temperature and relative humidity	Accuracy for the range of -20°C to 40°C is +/- 0.5 °C and 20-80% RH is +/-3% RH		Continuous logging at 5 minutes frequency
Thermistors	Zenthermik	Surface temperature	Accuracy in the anticipated range of 20 °C to 65 °C is +/- 0.3°C		Continuous logging at 5 minutes frequency
Thermal gun	Fluke	Surface temperature	Range: -18 °C to 275 °C; Target Spot: upto to 1 m +/- 2 %		Spot measurement

Table 2 shows list of instruments used during the monitoring. The study was conducted for a period of minimum 6 to 8 days at each district. The instruments are set on data recording frequency of 5-minute interval with continuous logging.

Data monitoring sheets were prepared for each house and updated daily. The sheet includes data downloading time, windows opening/closing time. The windows are kept open at night and closed during the day based on regular behaviour of the occupants. Typically, the windows were closed in the morning in between 9.30 am and 10.30 am and opened in the evening in between 5.30 pm and 6.30 pm for all 4 houses at each district.

The key performance indicators for this study are under-deck and over-deck surface temperature with and without cool roofs.

5. Key results and way forward

The outcome of the study is that the application of cool roof led to a reduction in under-deck and over-deck temperature during peak outside condition (day-time and clear sky). The temperature reduction varies based on the location and other factors such as the presence of false ceilings and roughness over the surface of the roof.

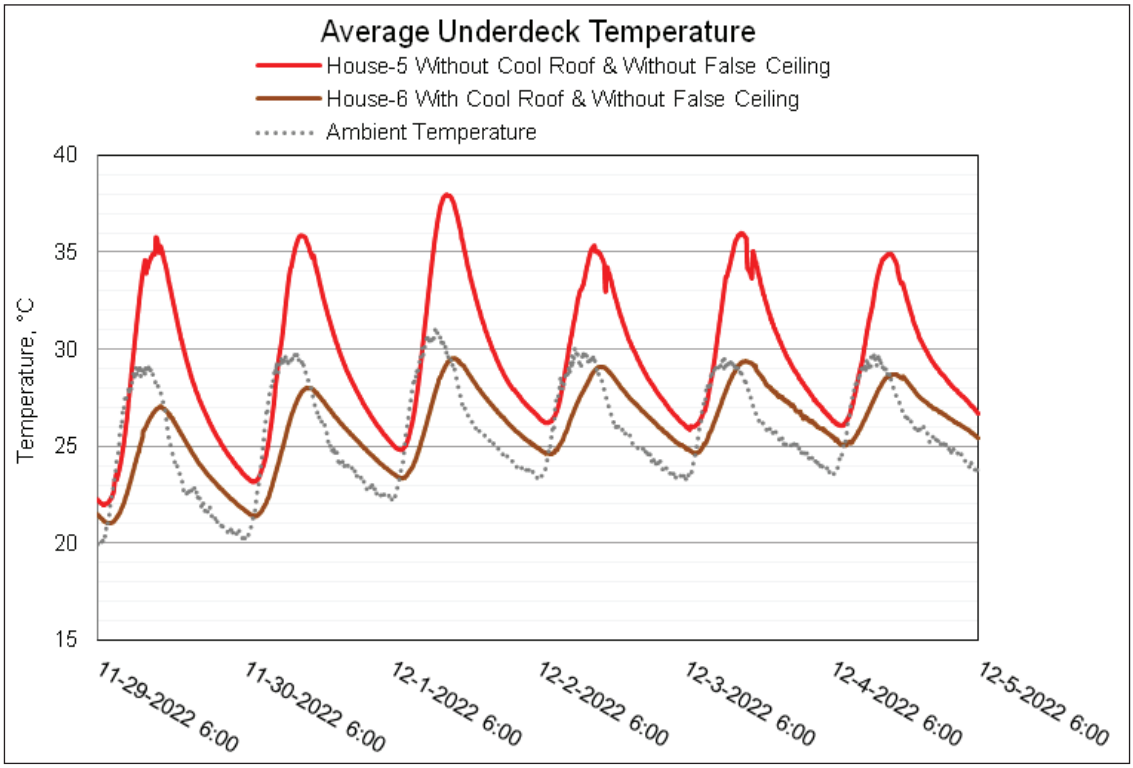

Figure 7. Comparison of under-deck temperature of two houses located in Samalkota, Kakinada, Andhra Pradesh - one with cool roof and one without cool roof. The houses do not have a false ceiling.

In Samalkot, Kakinada, Andhra Pradesh (Figure 7), the temperature reduction up to 9 °C was observed with the application of cool roof for houses without false ceilings. Similar trends are observed in other districts as well. A typical reduction of around 6–9 °C in under-deck temperatures was found when there is no false ceiling with cool roof application.

In Vellanki, Visakhapatnam, Andhra Pradesh (Figure 8), the temperature reduction up to 4 °C was observed with the application of cool roof for houses with false ceilings. Similar results were observed in other districts as well. A typical reduction of around 2–4 °C in under-deck temperatures was found when there is false ceiling with cool roof application.

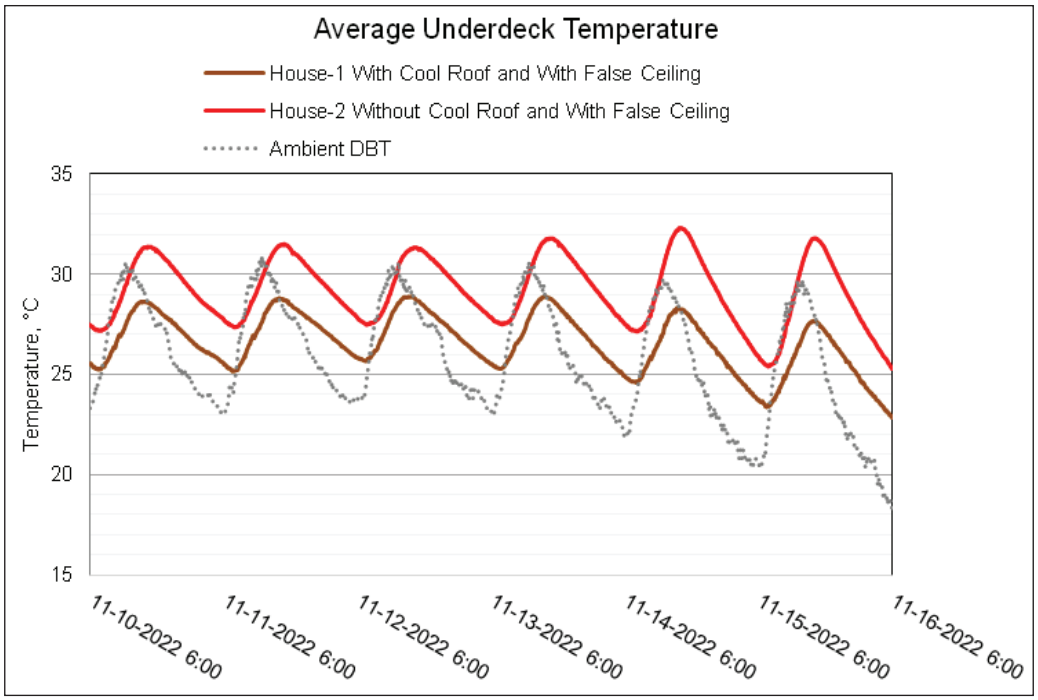

Figure 8. Comparison of under-deck temperature of two houses located in Vellanki, Vishakhapatnam, Andhra Pradesh - one with cool roof and one without cool roof. The houses have false ceilings.

In the Vellatur, Bapatla, Andhra Pradesh location (Figure 9), the over-deck temperature was observed to be about 11 °C less in houses with cool roof paint compared to those without. Similar results are observed in other districts as well. A typical reduction of around 10–12 °C in overdeck temperature was found with cool roof application.

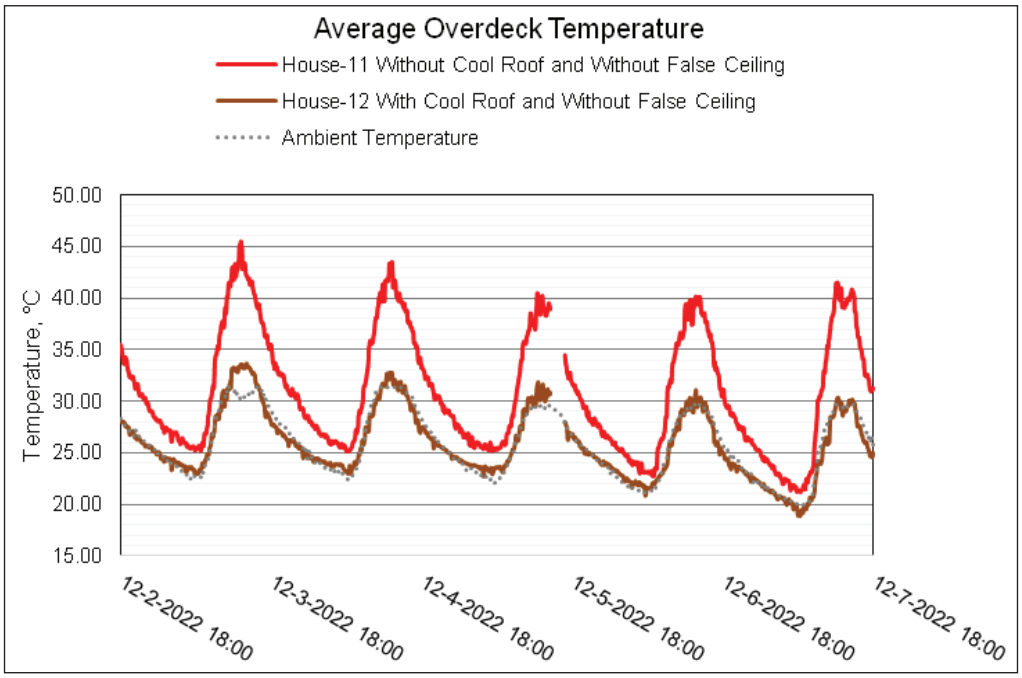

Figure 9. Comparison of over-deck temperature of two houses located in Vellatur, Bapatla, Andhra Pradesh - one with cool roof and one without cool roof. The houses do have false ceilings.

6. Supporting activities for cool roof adoption

- A Ready Reckoner on cool roof was prepared in the local language, which included the details of the types of cool roof materials, available manufacturers/suppliers, cost of the materials and its application process.

  (English version available at https://www.beepindia.org/wp-content/uploads/2022/12/Ready-Reckoner-Cool-Roofs-_English-Version_24-02-2023.pdf)

- Three dissemination programmes were organized at study sites – Vellanki, Vellatur and Samalkot village in Andhra Pradesh – that had about 350 participants. During the dissemination programmes, cool roof ready reckoner was distributed, and the participants/beneficiaries visited inside the houses applied with cool roof and have shared their positive experience and expressed that the temperatures in these houses are comparatively lower and more comfortable.

7. Way forward

Based on the study results, the study recommends the following:

- Cool roof material should be treated as one of the essential building materials and the application of the same may be initiated as a mandatory provision during construction.
- Cool roof materials should be incorporated in the Schedule of Rates (SoR) for effective implementation of the cool roof programme.
- For effective implementation of these kinds of initiatives, a cool roof policy should be notified with proper implementation framework.
- The cool roof application is recommended in the affordable housing scheme, i.e., AP Government's 'Housing for all poor' under Navaratnalu as one of the essential materials, which will benefit about 30 lakh households who are in the economically weaker sections of the society.
- The mandatory implementation of the cool roof programme not only increases the thermal comfort of the occupants and thereby reduces energy consumption but also contributes towards addressing the heat island effect.

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