

Understanding the Climate Sensitive Vernacular Architecture of Palle Chuwdu Middelu in Ramanapalle-village in Kadapa Division A.P, India

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Abstract- Vernacular architecture and climate are engaged in a happy marriage in any indigenously developed settlement. We documented and analyzed a vernacular Palle or village settlement such as Ramanapalli, Chennur which are located in tropical zone of hot and semi-arid climatic Kadapa region of Andhra Pradesh. Palle is a rural settlement in Kadapa district of Rayalaseema, India. It is particularly significant for architectural studies because it has been documented as an example of climate-sensitive vernacular architecture in the Rayalaseema region. The Palle form and structure come from many years of evolution and sharing knowledge. This shows how different physical and non-physical forces like weather, land, religion, culture, money, old building methods, and how people organize themselves have shaped them. These are made up of small groups of homes with thick walls, heavy roofs, small windows, and narrow streets. In villages like Chennur, Ramanapalle, and Rachinayapalle, there are different types of houses, known locally as 'Chowda or Dante Middelu'. The designs of these houses are usually rectangular or square, built using traditional methods that take into account the local climate. They are well suited to meet the everyday needs of the people living there. The people living in these houses adjust their daily activities to fit the natural qualities of the space around them. The house is designed and built in a way that responds to the hot and dry climate. This type of design is a form of passive architecture that uses local materials, thick walls, small windows, traditional flat roof with high thermal mass, and small vents near the roof but below it. These thick walls and heavy roof help absorb and slow down the transfer of heat. The small windows are placed carefully to reduce the amount of direct sunlight entering. However, the 'House form of Chowda Middelu' in Kadapa district is vanishing because of various reasons in recent years. Previously, this type of architecture and the way people lived were very responsive to the climate. But now, these traditional designs and habits are slowly changing into ones that don't take the climate or local surroundings into account. This research suggests the need for a set of guidelines that can help balance modern development with the traditional building methods used in the area.

Keywords - Kadapa region, Hot semi-arid climate zone, Palle chowdu midde, Climate sensitive, Sustainable architecture

I. INTRODUCTION

Usually, our buildings are considered as our third layer, like clothing, while the skin is the first. These three layers help keep our body temperature around 37°C throughout the year, no matter where we are living. Without exact ways to control the temperature, the different designs of buildings play a big role in dealing with weather and wind, helping us feel comfortable inside the building [1, 2]. Because of this, architecture and climate work together in any local community that is built naturally.

Knowing the vernacular architecture in terms of heat-humidity, air movement and light with respect to the surrounding physical environment provides energetic lessons for the present design endeavors. The familiar elements of particular regional architectural styles like use of natural materials and constructional with provision of verandahs, balconies,

courtyards, shutters are created to use the sun for warmth and light and to create shade and breeze for cooling. Climatic design lessons can be learned and inspiration can be sought by observation of the long tradition of vernacular architecture [3-5]. These are important especially in the context of energy concerns from all around the world and the alarming increase in air conditioning usage in the recent years [6, 7].

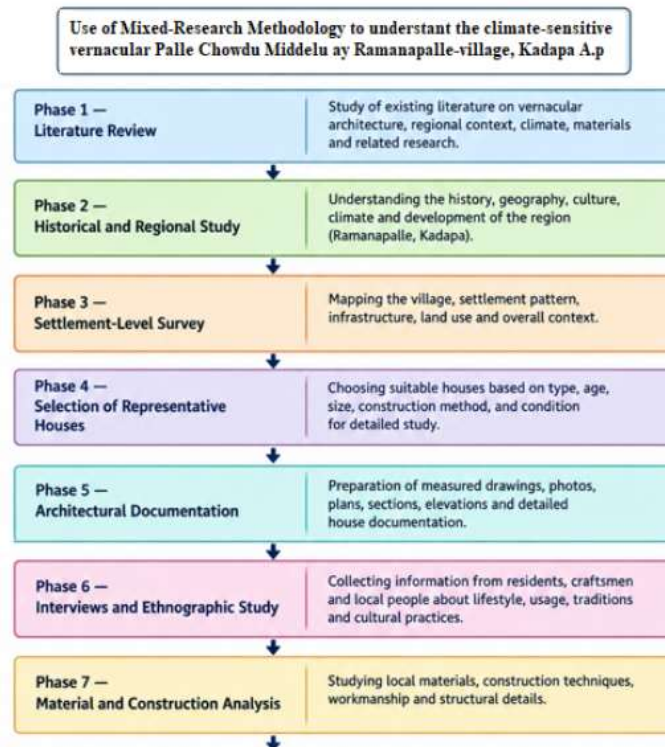
In India, buildings use the most energy compared to other countries in the Asia Pacific Partnership. Because there are not strict rules and many groups are pushing for more modern designs, more buildings are made with aluminum and glass. These buildings are mostly air conditioned, but they don't take into account the local climate or environment. Because of this, the buildings lose their unique local look and end up looking the same whether they are in the hot desert of Rajasthan or the cooler hills of the Himalayas [8].

On the other hand, traditional Palle houses, which are locally called "Chowdu Midde" in the Kadapa region of Rayalaseema, are good examples of buildings that have been designed to suit the hot semi-arid climate. The purpose of this research paper is to study different types of Pallelu, such as Velurupadu, Mittamidhapalle, Chennur, Ramanapalle and Rachinayapalle by observing at their architectural styles and how well their features and the overall settlement are suited to the local climate. This research study explains how a building environment that functions like a living organism, naturally sustainable because it uses various bioclimatic ideas during its original design, is closely connected with the way people live, the surrounding landscape, and uses resources with very little waste. The study is divided into two main sections: first, a study on how the built environment has developed over time, including how shapes and layouts have changed, how land was planned, how buildings were grouped together, and the materials and methods used in construction. Second, it looks at specific types of traditional homes and how they are designed to respond to the local climate, using natural construction materials and methods that help make the living conditions comfortable and suitable for the environment. When assessing

the settlement and the houses, factors like temperature, humidity, air movement, and sunlight are considered, along with how people use the space and live their daily lives.

II. Research Methodology:

There are different methods are applicable to conduct research as per the nature of study in architecture. For conducting research of vernacular architecture, the suitable research methods are mixed-research methods and case-study-based research methodology is generally the most suitable [9, 10]. To conduct the research study on 'Palle Chowdu Middelu' at Chennur mandal in Kadapa area, the author used a mixed-research method such as field documentation, measured drawings, interviews with households, elders and traditional craftsman's, application of local construction material and constructional technics and comparison with published literature. To understand and identify the climate-sensitive vernacular architecture of Palle Chowdu Middelu at Ramanapalle village in Kadapa division of Andhra Pradesh, the author derived and recommended the mixed-methodology of research showed in Fig-1.



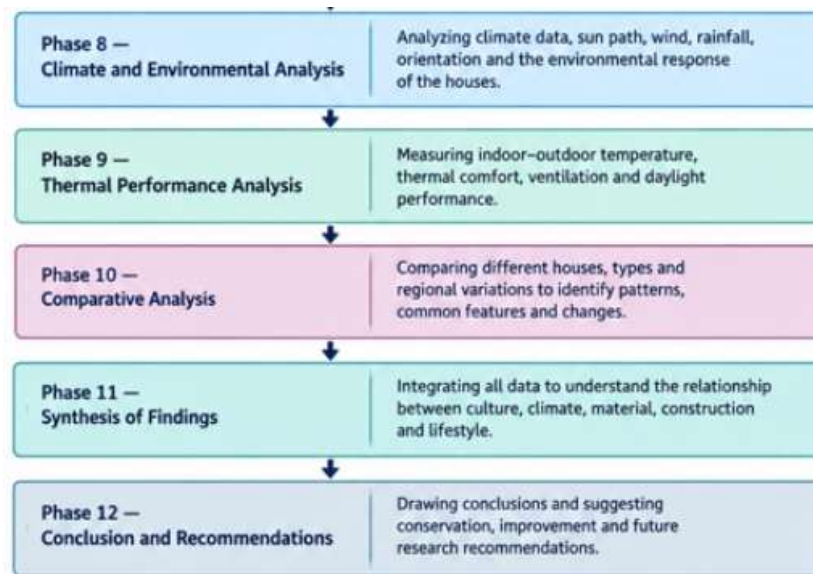


Fig-1: Use of Mixed-Research Methodology to understand the climate-sensitive Vernacular Palle Chowdu Middelu at Ramanapalle-village near Kadapa, A.P

III. RAMANAPALLI, A VERNACULAR SETTLEMENT IN KADAPA REGION OF A.P.

History & Location:

The wider Kadapa area has a long history of people living there connected to the Penna River area and the Rayalaseema farming land. This region was influenced by many South Indian kingdoms like the Pallavas, Chalukyas, Cholas, and later the Vijayanagara rulers. Pallelu near Chennur grew mainly because of farming, nearby water sources, raising animals, and village-based occupation. The villages of Ramanapalle, Rachinnayapalle, and Mundlapalle are part of the same group of rural communities [9]. Ramanapalli is a village located in Chennur mandal, YSR Kadapa district of Andhra Pradesh, India. Its coordinates are 14.54017° N and 78.80924° E. It lies about 8 km from Kadapa, which is a nearby big town. Ramanapalli still looks like a typical rural village from the Rayalaseema region showing in Fig-2.

However, because it is close to Kadapa city and Chennur, it has better access to roads, markets, schools and other city services [11]. During the field survey, village elders shared stories that show Ramanapalle is a big village. The people there are mostly

Reddies, with a smaller number from other castes like SC, Muslims, and others. The village's main sources of income are farming and small-scale selling. It is located near the Kurnul-Chittur highway, about 3 to 4 kilometers away. Since it is an interior village, its original look and way of life have not been much affected by city influences or land being used for big business [12].

Data Collection

The current analysis is based on data gathered during a development study that author conducted in this village between 2025 and 2026. The methods used to collect data include my field observations, household surveys, interviews with elders and craftsmen, as well as sketching, photographing, and making measured drawings of selected houses. This study is presented as architectural documentation [13]. The data collection combines architectural, social, environmental, and material surveys and is recommended. The data includes the physical layout, condition, use, materials, construction, history, location, and cultural significance of buildings. The methods used may involve sketching, photographs, measured drawings, and written analysis.

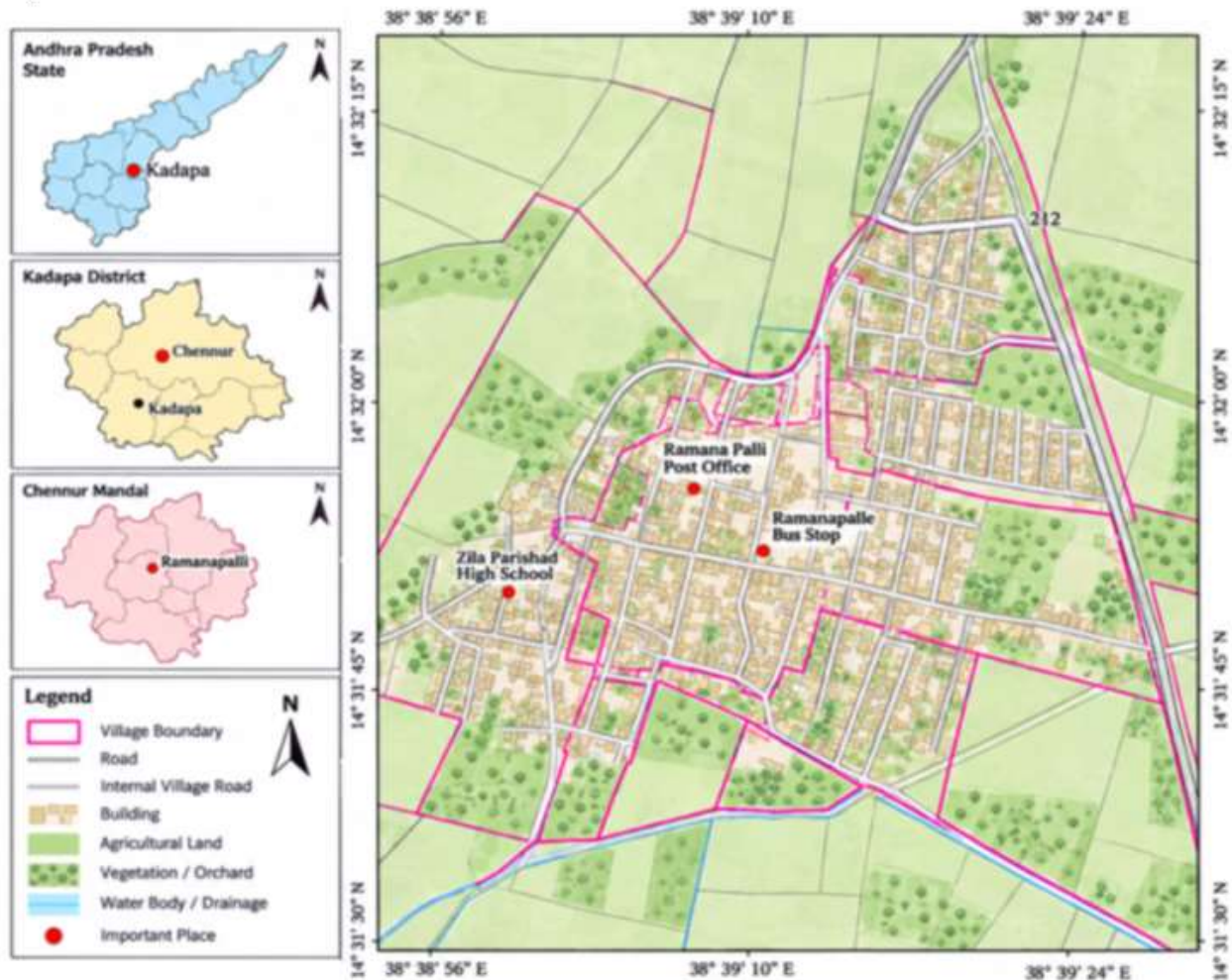


Fig-2: Location map showing Ramanapalle Village near Chennur, Kadapa district in Andhra Pradesh, INDIA
(Source: YSR Kadapa district map agency, 2026)

Climate Data:

The study area of Ramanapalle tropical climate zone broadly similar to the wider Rayalaseema region. The climate can broadly be described as hot, semi-arid with high summer temperature, strong solar exposure. The summer temperature frequently around 40°C to 45°C and the annual average temperature of about 29.5°C. Rainfall is irregular and annual is approximately 688.6mm. The area has seasonal humidity pattern like in winter 40-55% and in summer 30-40% [14]. The higher summer temperature produces such as intense heat gain through roofs and walls, high indoor temperatures during afternoon hours, strong solar radiation on east, west and south-facing surfaces, increased dependence on natural ventilation and considerable thermal stress on houses.

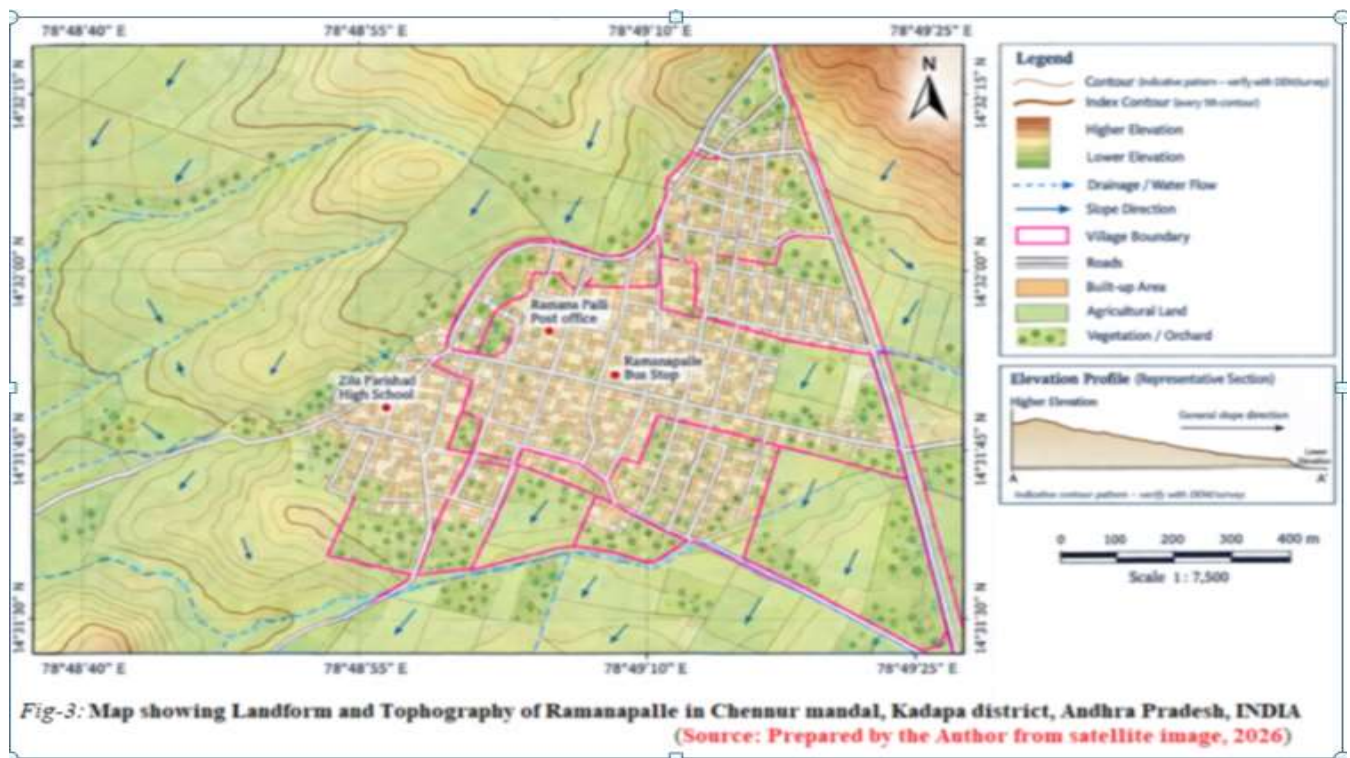
IV. CLIMATE APPROPRIATENESS OF THE SETTLEMENT

The settlement pattern, house orientation, street configuration, vegetation, building materials and shaded transition spaces all influence the local microclimate. Palle settlements in the Kadapa region of Andhra Pradesh show several characteristics that can be understood as responses to the regions with hot semi-arid climate [15]. Kadapa experiences high summer temperatures, strong solar exposure and seasonal rainfall. The district administration reports summer temperatures that can reach approximately 40–45°C during summer months. Climate appropriateness of the settlement mostly depends on landform and topography, morphological development, settlement form and site planning, cluster planning, street alleys, construction

materials and methods such as sub-structure, super structure, openings, color and texture.

Landform and Topography: The location coordinates of Ramanapalle latitude are 14.5409 N and longitude is 78.8109 E. The village is located on the gently sloping terrain with elevation declining from north-east towards the south-west. Contours indicate undulating topography with low hillocks in the north-east and flatter field in the south-east. Surface drainage flows towards the south-west through natural and

agricultural channels. The settlement is situated on relatively higher ground, with agricultural lands in the lower area shown in Fig-3. The geological character, availability of local stone, seasonal rainfall and predominantly hot climate together influence settlement location, building materials, foundation systems, drainage patterns and the climatic adaptation of vernacular houses [16]. As a geographical location and hot-semi-arid climatic, summer breezes are usually hot and add to the discomfort. The village has a gently sloping terrain, towards river Penna.



Morphological Development

The morphological development of villages in the YSR Kadapa region reflects the interaction of terrain, water availability, agriculture, caste/community organization, climate and changing land-use patterns. Traditionally, settlements developed incrementally at the center of agricultural land, water sources and community spaces. With the development of agriculture, villages expanded from the original settlement core toward surrounding agricultural fields. Ramanapalle settlement morphology generally responded to high summer temperatures, strong solar exposure and seasonal rainfall. Narrower streets, shaded transitional spaces, thick masonry walls and relatively controlled openings helped moderate the outdoor and indoor environment [17]. The history of morphological development

of Ramanapalle village is described in the following phase showed in Fig-4.

1960s-Early Phase: In the early phase, small settlement core and few houses are along the main-road, agricultural land is dominant.

1980s-Expansion Phase: Linear growth of the settlement is taken place along the main road. This leads formation of internal lanes, this increase housing units along the internal lanes.

2000s-Consolidation Phase: At this phase, spreading towards the periphery in all directions. Development of bus-stop and public facilities. More grid-like street pattern take place.

2020s-Present Phase: During this phase, infill development is taken place and improved road network. Mixed land-use such as residential, rural level public and commercial.

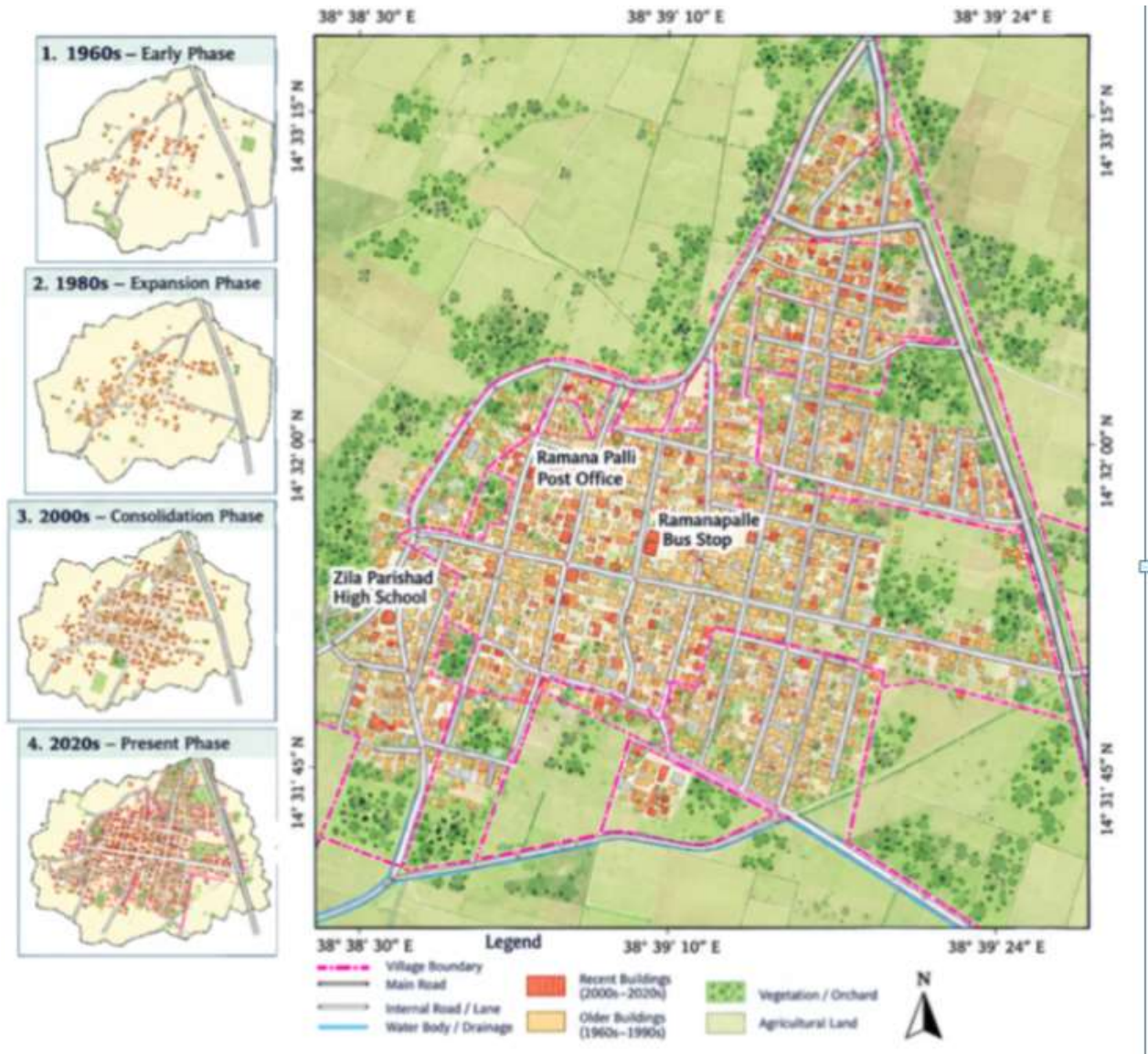


Fig-4: Map showing Morphological Development Ramanapalle from (1960s to 2020s)
(Source: Prepared by author from satellite inamd, 2026)

Settlement Form and Site Planning

Settlement form and site planning describe how a village occupies its physical site and how houses, streets, public spaces, agricultural land, water systems and other daily activities are spatially organized. In rural area, settlement form

is not determined only by house design; it evolves from the interaction of topography, climate, water availability, agriculture, transportation, social organization, economy and historical development [14, 17]. In the study area, the settlement form and site planning is taken place in four ways.

As per the records, settlement form and site planning at first took place along the normal foot-path or walk-way that is at early phase in 1960s. Secondly, linear form and planning took place along the main footpath/road and this led formation of internals to construct new-housing units and it will be happen in 1980s. Thirdly, spreading towards the periphery in all directions like a consolidated phase. At fourth, infill development is taking place with improved pucca roads network, mix-used development and so on [18].

Cluster Planning

It is the arrangement of a group of houses and associated with verandahs, lanes, work areas, cattle spaces and community facilities into a relatively coherent spatial unit. Instead of treating each house as an independent building, cluster planning considers the relationship between houses, circulation, open spaces, social activities, climate and the surrounding landscape [17, 18]. In rural settlements, clusters commonly develop incrementally according to family relationships, occupation, land availability, accessibility, topography and local environmental conditions. In the study area, the houses and other structures are grouped closely tighter in a compact cluster settlement form, while agricultural field and other open lands surround the settlement.

“Rural clustered planning is a settlement pattern in which residential buildings are organized in a compact group around streets, lanes and shared community spaces, while agricultural and open lands are generally located around the settlement. The pattern develops in response to social relationships, agricultural practices, topography, water availability, transportation and environmental conditions.”

Street Alleys

Street alleys are narrow secondary or tertiary passageways within a settlement that provide access between houses, open spaces, service areas, and sometimes agricultural fields in village settlement. They are usually narrower and less formal than the main village streets. In a vernacular rural settlement, an alley may develop organically as houses are constructed around an existing main street or path connections between dwellings and the agricultural fields [19]. In general, the street alleys in a village includes main-street → secondary street → street alley → house entrance. In the study area of Ramanapalle is dominated by main-streets and secondary-streets and street-alleys are dominating at present scenario too with narrow.

Construction Materials & Methods

In and around the settlement, we can find plenty of materials like Kadapa stone or black limestone, hard bricks, slate, wood,

lime-mortar, and mud-mortar. Because these materials are locally available, they are widely used in building all structures. For the foundation and plinth, as well as the walls, Kadapa black limestone or burnt bricks made locally are used, and mud-mortar is used as the binding material. The rich communities use lime-mortar for the entire masonry work. Additionally, a mixture of mud, some local termite powder, and water-proofing admixture made from Karakkai or Gachakaya is commonly used for foundations, plinths, walls, roofs, and floors to control the termite problem [17]. Most of the houses are single storied constructions with rectangle-built form with traditional flat roof locally known as ‘Chowdu Midde’ with gentle slope. Interesting, all the houses have medium plinths (40cm-60cm), to offer protection from rural floods, no entry of toxic snakes. Interesting, the roofs do not feature any eaves gutters to collect rainwater from the roofs.

Foundation and Plinth

In the traditional houses of the Kadapa region in Rayalaseema, the foundation and plinth were made using local materials like burnt bricks, black-limestone, and rubble stones, all bind together with mud or lime-based mortar. This way of traditional structure was suited to the hot and dry climate of the area, used the materials that were easily available, followed traditional building methods, and helped protect the earthen walls from rain and dampness. In the area of Ramanapalle, the foundation was usually made of rubble stones and mud mortar. The mud mortar was made from clay mixed with a small amount of sand and Karakkai or Gachakaya powder to prevent termites. The plinth above the foundation was built with black-limestone blocks and mud mortar, and it was raised up to a height of 45cm to 60cm.

Walls and Roof

The need to use thermal mass to create a longer time lag for better insulation was known by local builders and craftsmen. Because of this, walls were made from stone, brick, or mud, and the roof was constructed with local wood. On top of these, a thick layer of saline soil, called “Chowdu Matti” locally, was applied, ranging from 5 cm to 6.5 cm in thickness. This helped control the transfer of heat from the roof. Most houses, whether owned by rich or poor people, were built in the same way, except for the type of binding material used, which could be either mud mortar or lime mortar.

Mud walls are made by mixing clay lumps well and have a thickness of 45cm to 50cm, reaching up to a height of 3.5m to 5m. Most houses are built using Kadapa black lime-stone with either mud or lime mortar, and the thickness of these walls is between 50cm to 60cm, with the same height as the mud walls.

In the study area, most walls are made of locally produced kiln bricks and are bonded with local mud mortar because of the area's location. For both mud and brick walls, the outside and inside surfaces are coated with a mix of mud and cow-dung. In some cases, walls are finished with lime plaster. The inside walls are coated with white wash made from local lime-stone. Walls made from stone are bound with mud plaster, and the inside surfaces are plastered with a mix of mud and cow-dung, then white washed and out-side there is no plastering.

Coming to the roof, it is almost like RCC-roof but not made of reinforced cement concrete and it is similar like Bagra flat lime-roof use in traditional house of Tehla near Jaipur. It is 100% same as traditional flat-roof in Ethiopia traditional villages in very hot-climate zone like Afar region. The roof is made of local wooden frame work. At first, horizontal wood beams (beams of palm/neem/teak) bout 25cm to 35cm depth and 15cm to 20cm width laid in between the thick walls in short-span direction. The spacing of beams depends up on the wall-span and its cross-sectional area, generally 60cm-80cm. Over that less diameter of local sticks (4cm-6cm □) laid very nearby. Over that locally made bamboo spread to the whole area. A layer of neem-leaver laid over the mat. Finally selected Chowdu Matti (saline or alkaline soil with a thickness of 5cm-6cm fill it. The building of whole roof is locally called as 'Cowdu Midde or Dantele Midde'.

The construction of roof style is changed from a one-half century onwards where the traditional house constructing near to the major roads. The wooden roof-structure replaced with iron-beams, Kadapa stone slates and chowd matti or saline soil. The steel I-section (locally known as steel dantelu) are placed between the thick-walls @ 60cm -80cm c/c. Over that 7.5cm x 2.5cm thick local reapers are Kadapa black-stone slates (60cm length x 45cm width and 6cm thick) are laid and the gap between slate are filled with local lime-mortar. Finally selected chowdu matti with a thickness of 5cm-6cm fill it.

Openings, Color and Texture

The design of the openings in Rayalaseema traditional houses came from the need to adapt to the climate. The main entrance door in traditional Ramanapalle house is usually a solid timber double-leafed door set in a thick mud/stone/ brick-wall. It is placed in the front verandah and main living-room. The door frame and shutter made of local hardwood of teak or red sandalwood. The lower part of the of the door wooden threshold 'Gadapa' which separate the in-side and out-side of the house. The door generally decorated with simple curving and bradd or iron fitting. It provided security, privacy and a dignified entrance to the house. Over the door head a decorative

wooden lintel is provided. The typical dimension of door is 1.0-1.2m door width, 2.1-2.4m height and the threshold height is 0.15-0.30m.

Windows are small or medium set in a thick mu/stone/brick wall at both sides of the main-door. It is placed in the shaded front-verandah with suitable sill height to allow light and air while maintaining the privacy. They are usually made of local timber like neem/teak/red-sandalwood. This helps reduce the strong contrast of light between the view outside and the window area. The typical dimensions of window are 64cm - width and 85cm-height. Small vents are placed near the roof ceiling inside the roof, helping to let out the hot air through a process called buoyancy-driven ventilation. This system offers good protection against heat, hot air drafts, and bright glare. As a result, most of the light inside comes from soft, reflected and diffused light.

V. HOUSES TYPOLOGIES

In the Kadapa region of Rayalaseema in Andhra Pradesh, the types of houses at present include traditional and modern ones. Right now, most people live in traditional houses, which make up more than 85%. These are called "Chowdu or Dentelu Middelu" in most rural areas of Kadapa. They are popular because they are well-suited to the local climate and help save energy by using eco-friendly building materials and methods [20]. In the study area, the traditional house types are either detached or semi-detached, depending on the family's economic status and size. These types are explained in detail based on field studies and research done by the author in the area.

Detached Chowdu Midde

A detached house is a house that stands independently on its own plot of land and does not share walls with another house. There is usually an open space around the house. This type of houses is mostly constructed by economically well is rural or urban settings. The detached chowdu midde in the study area of Ramanapalle village are dominated during early-phase (1960s) and expansion phase (1980s) due to dominating percentage of landlords and after that its dominance are decrease due to consolidation and present Phase. The detached traditional chowdu medde is house for moth humans and live-stocks, such as house is known as "Byre-dwelling or Housebarn" [21].

The author did a field study and recorded information about a detached house owned by Errama Reddy Munnama. This house was built in the 1960s by the owner's father. The house has several rooms, including the owner's room, a store for crops, a family room, a shed for animals, and a kitchen. The size of the

house is 13.45m x 11.4m. The outer walls are made of thick black stone masonry with mud mortar, and they are about 70cm thick. There are three main doors. One faces the main village road, another is opposite the backyard and is used only for people to enter, the third connects to a street alley for animals to come in and out. The internal walls are made of a mix of mud, clay, and cow dung slurry, then plastered and painted with traditional white wash. Each room has one internal door and window. The floors of the rooms are compacted and finished with Kadapa black stone slates. The floor for the cattle is simply compacted and leveled.

The roof of the house is traditional flat roof made of local wood, bamboo mat and saline soil locally called as “Choedu Midde” to protect the interior space from high solar radiation. At first, horizontal main wood beams of palm/ neem/teak (about 20cm width and 35cm depth) placed between the thick walls in short-span direction at 60cm to 80cm center-to-center. Over that 4cm-60cm diameter well-seasoned of local sticks laid very perpendicular to the main beams very close. Over that locally made bamboo mats spread to the whole area and then layer of neem-leaver laid over the mat. Finally, the entire roof area filled with a less white saline soil locally known as “Chowdu Matti” about 8cm-12cm thickness. This roof is called as in local terminology ‘Cowdu Midde or Dantele Midde’. The whole traditional architectural design and construction methods with the application of local materials protect the building from high-solar-radiation and keep the home cool in summer and warm in winter, architectural and construction details are showed in Fig-5.

Semi-detached or Row-Chowdu Midde

This kind of housing started appearing in Ramanapalle from the 1980s up to the 2020s because of several reasons, like changes in family structures from nuclear families to joint families and then to extended families. The joint family model led to the development of semi-detached houses, especially after two brothers from a nuclear family got married. These semi-detached houses have shared verandahs facing the main street, and the houses themselves have two to three rooms built around a common backyard with a central shared wall. All the family members use the front verandah and the backyard as shared spaces for everyone and the internal rooms used for their individual family.

The roof is built using materials found locally, such as wood, bricks made from local clay, and lime mortar. Initially, thick horizontal wooden beams are placed between the walls, running in the shorter direction. On top of these beams, a layer of wooden planks is laid very closely and fixed with wooden pegs or nails that go straight across the main beams. Then, bricks are carefully stacked on top of the wooden planks in a

proper pattern without using any mortar. The top layer of bricks is covered with lime mortar, which is then leveled and smoothed, just like a Madras terrace roof, and it has a slight slope towards the street. To reach the roof-top, a ladder made of bamboo is used. All architectural and construction details of semi-detached house showed in Fig-

VI. BUILDING THERMAL PERFORMANCE ANALYSIS

Thermal performance analysis is the systematic study of how a traditional house responds to the local climate and maintains indoor thermal comfort (cool in summer and hot in winter) using locally available materials, construction techniques, building orientation, openings, shading, roof forms, and natural ventilation [27]. Solar heat transfer can take place spontaneously in the form of temperature from low-to-high. In built environment, heat flow or transfer can take place mostly by conduction, convection, radiation and evaporation. The maximum percentage of heat transfer through conduction and the about of heat transfer depends up on temperature difference, thickness of solid medium, area of exposed surface, time for which heat flow takes place, conductivity of the medium and density of the medium [26]. The amount of heat transfer through conduction is calculated by the formula (Q_c) = $A \times U \times \Delta T$

Where:

- ⇒ Q_c = Conduction heat flow rate in W
- ⇒ A = Surface area in m^2
- ⇒ U = Material heat transmittance value in $W/m^2 \text{ deg C}$
- ⇒ ΔT = Temperature difference (out-side and inside).

VII. STRENGTH AND LIMITATIONS

The building thermal analysis generally examines the parameters of climate, building orientation, wall materials, roof, openings, natural ventilation, thermal mass, shading, indoor comfort and the details given Table-1.

The basic thermal analysis for a building includes the process of to know thickness of materials (L), material thermal conductivity (K), resistance of the individual building material ($R = L/K$), total thermal resistance (RT) = $[1/f_o + 1/f_i] + R_1 + R_2 + \dots$ and overall heat-transfer coefficient (U) = $1/R_t$ [28]. Finally, the heat flow through a building element can be estimated as $Q = UA\Delta T$. Thermal Performance calculation of

“Walls and Roof) for Traditional Chowdu Mudde and RCC building in Ramanapalle-village at Kadapa region of A.P, INDI as follows

Table-1: Building Thermal Performance Analysis

Parameter	Analysis type	Typical response
Climate	Solar radiation, Temperature, humidity and wind and its direction	House adapted to the local climatic conditions
Orientation	House direction and exposure to solar	To minimize the unwanted solar heat-gain especially during hot season
Construction materials	Materials thickness, Thermal conductivity, total thermal resistance,	Thick walls made of mud/ stone/mu-cob, ret-brick plastered with lime and mud-with cow-dung mortar on both in out-door walls.
Walls	Thick masonry walls	Thick masonry walls made of local materials to delay heat-transfer
Roof	Heat gain through roof	Thick-flat-roof to delay heat transfer
Openings	Size, position and shading	Suitable size of openings (door & windows) placed at deep front-verandah.
Natural ventilation	Air movement in the house	Naturally controlled air movement will taken place inside and out-side through shaded openings
Thermal mass	Heat storage and time-lag	Application of all natural materials to moderate in-door temperature
Indoor comfort	Naturally operative temperature, relative humidity and air speed	Proved with accepted comfort criteria

Wall Type-1: External stone masonry wall:

This stone masonry wall made of Kadapa black-stone with mud-mortar. The inner wall surface traditionally plaster with mixture of mud with cow-dung with a thickness of 2.5cm. Thermal conductivity of black stone wall and mud with cow-dung plaster are 1.5 W/m-K and 1.19W/m-K and the wall details are given in Fig-a

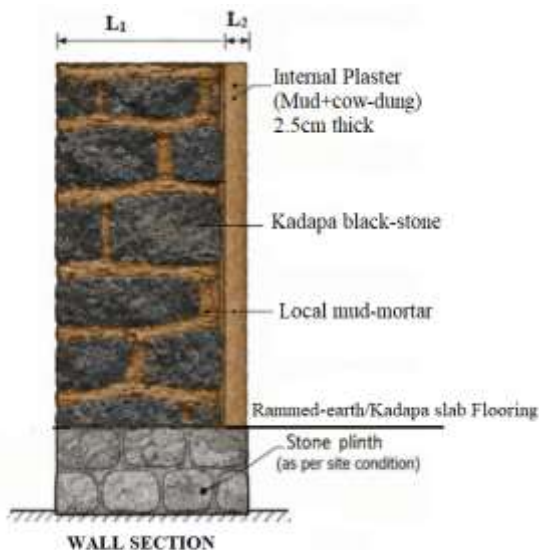


Fig-a: Details of Kadapa-stone Masonry External-wall in Chowdu Midde

Thermal Calculations:

Thicknesses of materials are;

Kadapa Black-stone thickness (L1) = 73cm = 0.73m

Inside mud with cow-dung plaster (L2) = 2.5cm = 0.02m

Thermal conductivity of materials is;

Thermal conductivity of black stone wall made of mud-mortar (K2) = 1.5 W/mK

Thermal conductivity of mud with cow-dung mortar (K2) = 1.19 W/mK

Thermal resistance (R) = $\frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$

$$R_1 = \frac{L_1}{K_1} = \frac{0.73}{1.5} = 0.486$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.025}{0.81} = 0.030$$

Total thermal resistance both side cement plastered brick wall

$$(R_T) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_1 + R_2 = (0.0515 + 0.125) + 0.486 + 0.030 = 0.693$$

$$\text{For walls, } \frac{1}{f_i} = 0.125, \frac{1}{f_o} = 0.0515$$

$$\text{Thermal transmittance (U)} = \frac{1}{R_T}$$

$$= \frac{1}{0.693}$$

$$= 1.443 \text{ (W/m}^2 \text{ K)}$$

Wall Type-2: Thick Masonry External Mud-cob wall: This mud masonry wall made of well mixed mud-cob at a thickness of 55cm. Both wall surface plaster with mud cow-dung 2.5cm thick. Thermal conductivity of mud cob-wall and cow-dung plaster are 0.85 W/m-K and 0.81 W/m-K and the wall details are given in Fig-b.

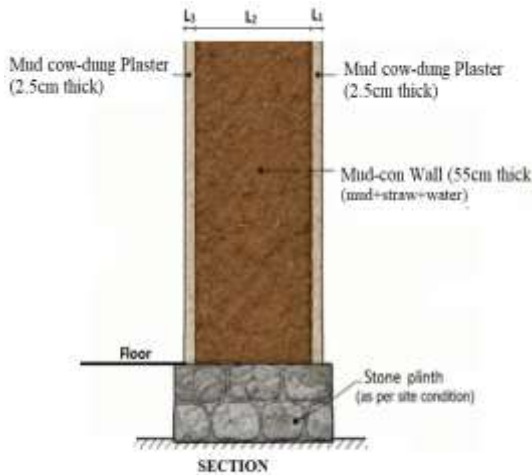


Fig-b: Details of Mud-cob External Masonry wall in Chowdu Midde

Thermal Calculations: Thicknesses of materials are;

- Out-side mud cow-dung plaster (L1) = 2.5cm = 0.025m
 - Mud-cob wall (L2) = 55cm = 0.55m
 - In-side mud cow-dung plaster (L3) = 2.5cm = 0.025m
- Thermal conductivity of materials is;

- Thermal conductivity out-side mud cow-dung plaster (K1) = 0.81 W/mK
- Thermal conductivity of mud cob-wall (K2) = 0.85 W/mK
- Thermal conductivity wall in-side mud cow-dung plaster (K3) = 0.81 W/mK

Thermal resistance (R) = $\frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$

$$R_1 = \frac{L_1}{K_1} = \frac{0.025}{0.81} = 0.031$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.55}{0.85} = 0.64$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.02}{0.81} = 0.031$$

For walls, $\frac{1}{f_i} = 0.125$, $\frac{1}{f_o} = 0.0515$

Total thermal resistance both side cement plastered brick wall

$$(RT) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_1 + R_2 + R_3 = (0.0515 + 0.125) + 0.031 + 0.64 + 0.031 = 0.8785$$

$$\text{Thermal transmittance (U)} = \frac{1}{RT} = \frac{1}{0.8785} = 1.13 \text{ (W/m}^2 \text{ K)}$$

Wall Type-3: Thick Masonry External Mud-cob wall:

This mud masonry wall made of well mixed mud-cob at a thickness of 55cm. The out-side wall surface plaster with lime-mortar 3cm thick and in-side wall plaster with mud cow-dung plaster approximately 2.5cm thick. Thermal conductivity of mud with cow-dung plaster and mud cob wall are black stone wall and mud with cow-dung plaster are 0.81 W/m-K, 0.85 W/m-K and 0.95 W/m-K.

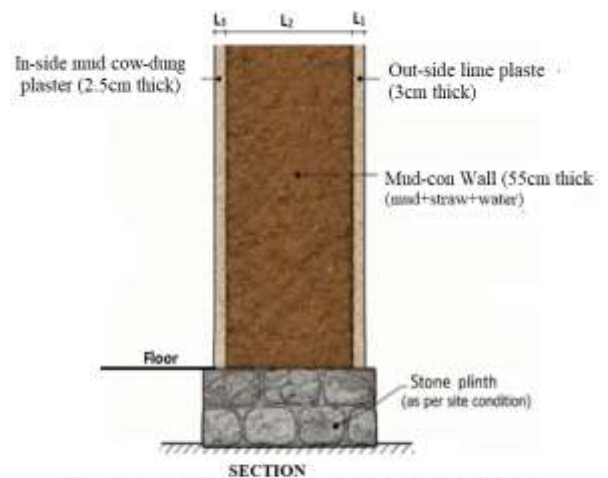


Fig-c: Details of Mud-cob External wall in Chowdu Midde

Thermal Calculations: Thicknesses of materials are;

- Out-side lime-plaster thickness (L1) = 3cm = 0.03m
 - Mud-cob wall (L2) = 55cm = 0.55m
 - In-side mud-plaster thickness (L3) = 2.5cm = 0.025m
- Thermal conductivity of materials is;

- Thermal conductivity wall out-side lime plaster (K1) = 0.95 W/mK
- Thermal conductivity of mud cob-wall (K2) = 0.85 W/mK
- Thermal conductivity wall out-side mud plaster (K3) = 0.81 W/mK

Thermal resistance (R) = $\frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$

$$R_1 = \frac{L_1}{K_1} = \frac{0.03}{0.95} = 0.031$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.55}{0.85} = 0.64$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.025}{0.81} = 0.030$$

Total thermal resistance both side cement plastered brick wall

For walls, $\frac{1}{f_i} = 0.125$, $\frac{1}{f_o} = 0.0515$

$$(RT) = [1/f_o + 1/f_i] + R_1 + R_2 + R_3 = (0.0515 + 0.125) + 0.031 + 0.64 + 0.030 = 0.8775$$

$$\text{Thermal transmittance (U)} = 1/RT = 1/0.8775 = 1.139 \text{ (W/m}^2 \text{ K)}$$

Wall Type-4: Thick Masonry External Brick-wall: This wall is made of locally made burnt bricks at a thickness of 40cm. The out-side and inside wall surface plaster with lime-mortar about 3cm. Thermal conductivity of lime mortar and burnt brick are 0.95 W/m-K and 1.0 W/m-K.

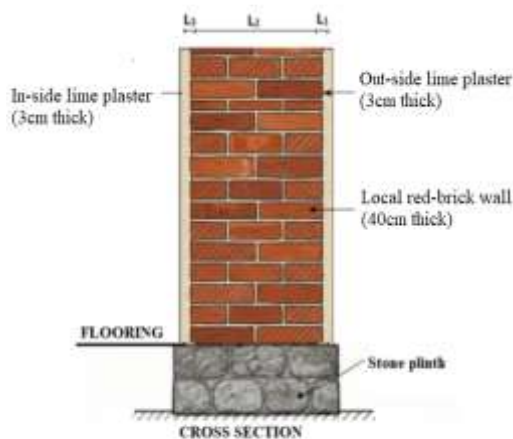


Fig-d: Details of Local Red-brick wall in Chowdu Midde

Thermal Calculations: Thicknesses of materials are;

- Out-side lime-plaster thickness (L1) = 3cm = 0.03m

- Mud-cob wall (L2) = 40cm = 0.4m

- In-side mud-plaster thickness (L3) = 3cm = 0.03m

Thermal conductivity of materials is;

oThermal conductivity wall out-side lime plaster (K1) = 0.95 W/mK

oThermal conductivity of mud cob-wall (K2) = 1.0 W/mK

oThermal conductivity wall in-side lime plaster (K3) = 0.95 W/mK

$$\text{Thermal resistance (R)} = \frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$$

$$R_1 = \frac{L_1}{K_1} = \frac{0.03}{0.95} = 0.031$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.40}{1.0} = 0.4$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.02}{0.81} = 0.031$$

Total thermal resistance both side cement plastered brick wall

For walls, $\frac{1}{f_i} = 0.125$, $\frac{1}{f_o} = 0.0515$

$$(RT) = [1/f_o + 1/f_i] + R_1 + R_2 + R_3 = (0.0515 + 0.125) + 0.031 + 0.4 + 0.031 = 0.6385$$

$$\text{Thermal transmittance (U)} = \frac{1}{RT} = \frac{1}{0.6385} = 1.566 \text{ (W/m}^2 \text{ K)}$$

Roof Type-1: Chowdu Midde

It is a traditional flat roof made of local wood frame (local sticks lattice), bamboo mat, Neem leave, saline soil (chowdu matti). The materials and constructional details are shown in Fig-e.

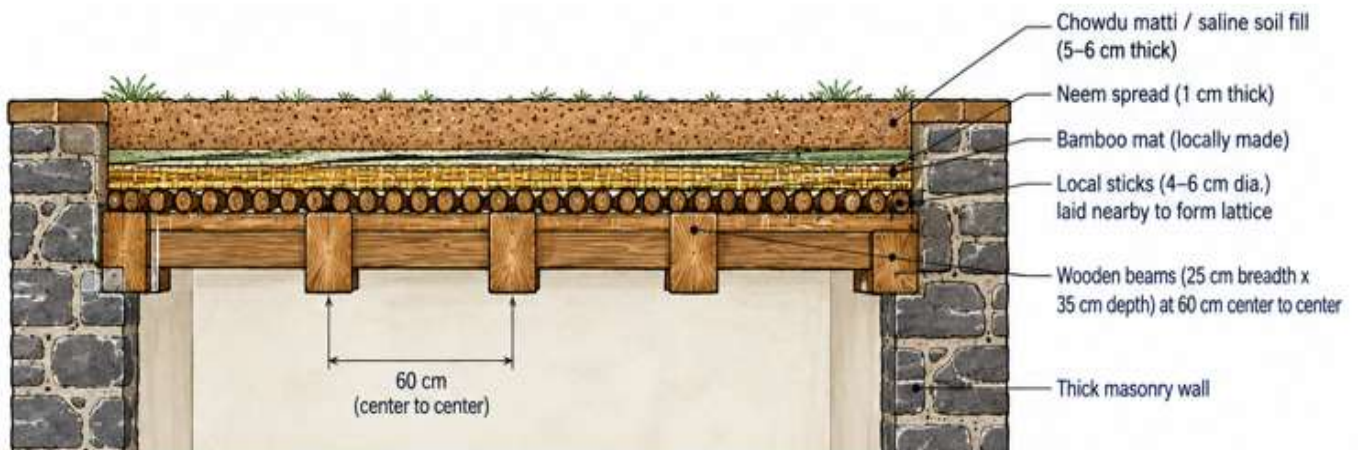


Fig-e: Sectional details of Traditional Flat Roof for Chowdu Middelu at Ramanapalle village, Kadapa region, A.P

Thermal Calculations

Thicknesses of materials are;

- Thickness of Saline soil filling (L1) = 5cm = 0.05m

- Thickness of Neem leaves-layer (L2) = 0.5cm = 0.005m

- Thickness of local made bamboo mat (L3) = 1cm = 0.01m
- Thickness of local sticks lattice (L4) = 4cm = 0.04m

Thermal conductivity of materials is;

- Thermal conductivity of Saline soil (K1) = 0.35 W/m-K
- Thermal conductivity Neem leaves (K2) = 0.055 W/m-K
- Thermal conductivity bamboo mat (K3) = 0.35 W/m-K
- Thermal conductivity of local stick lattice (K4) = 0.15 W/m-K

Thermal resistance (R):
$$R = \frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$$

$$R_1 = \frac{L_1}{K_1} = \frac{0.05}{0.35} = 0.142$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.005}{0.055} = 0.091$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.01}{0.35} = 0.028$$

$$R_4 = \frac{L_4}{K_4} = \frac{0.04}{0.15} = 0.266$$

Total thermal resistance traditional chowdu midde or flat-roof

$$(RT) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_2 + R_3 + R_4 = (0.0515 + 0.171) + 0.142 + 0.091 + 0.028 + 0.266 = 0.7495$$

Thermal transmittance (U) = $\frac{1}{RT}$

$$= \frac{1}{0.7495} = 1.334 \text{ (W/m}^2 \text{ K)}$$

Roof Type-2: Chowdu Midde

It is a traditional flat roof made of local wood frame, red-bricks and lime-mortar at roof-top. The materials and constructional details are shown in Fig-f.

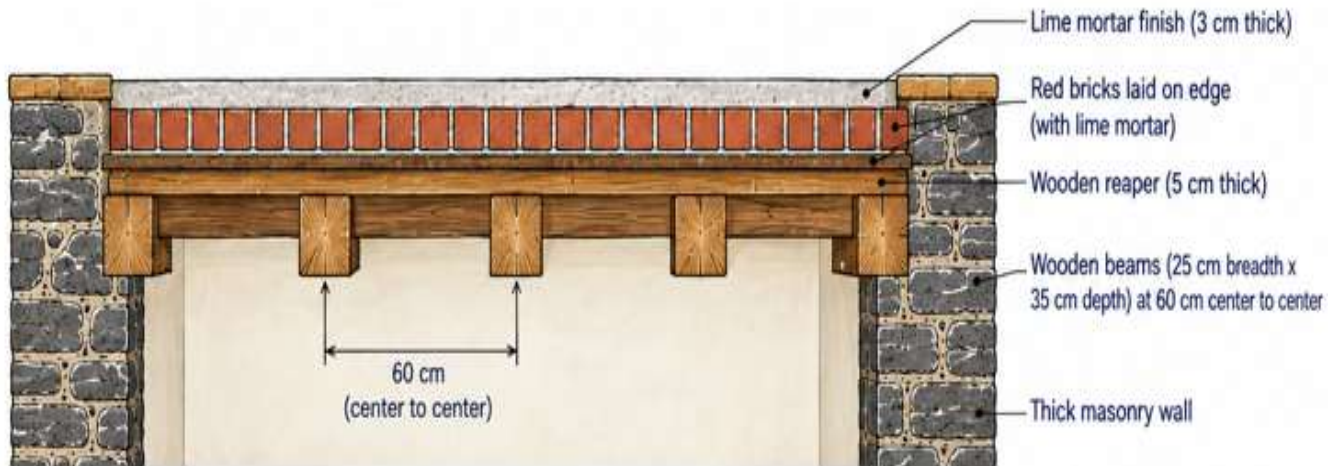


Fig-f: Sectional details of Traditional Brick Flat-roof for Chowdu Middel at Ramanapalle-village, Kadapa region, A.P

Solution:

Thicknesses of materials are;

- Local lime-mortar roof-finishing (L1) = 3cm = 0.03m
- Edged red-brick on flat roof (L2) = 9cm = 0.09m
- Ordinary local dry timber reaper (L3) = 2cm = 0.02m

Thermal conductivity of materials is;

- o Thermal conductivity of lime-mortar (K1) = 0.70 W/m-K
- o Thermal conductivity red-brick (K2) = 0.6 W/m-K
- o Thermal conductivity dry local wooden reaper (K3) = 0.11 W/m-K

Thermal resistance (R):
$$R = \frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$$

$$R_1 = \frac{L_1}{K_1} = \frac{0.03}{0.7} = 0.042$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.09}{0.6} = 0.15$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.02}{0.11} = 0.18$$

Total thermal resistance native chowdu midde or flat-roof.

$$(RT) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_1 + R_2 + R_3 + R_4 = (0.0515 + 0.171) + 0.042 + 0.15 + 0.18 = 0.5945$$

Thermal transmittance (U) = $\frac{1}{RT}$ **RCC building External**

Brick-wall:

This is made of made burnt bricks at a thickness of 22.86cm. The out-side wall surface plaster with cement mortar about 2cm thick and internal wall surface plastered with cement mortar about 1.5cm. Thermal conductivity of burnt brick wall and cement mortar are 0.80 W/m-K, 0.72 W/m-K.

Solution:

Thicknesses of materials are;

- Thickness of out-side cement plaster (L1) = 2cm = 0.02m
- Thickness of burnt brick-wall (L2) = 22.86cm = 0.2286m

- Thickness of In-side cement plaster (L_3) = 2cm = 0.02m
- Thermal conductivity of materials is;
- Thermal conductivity wall outer cement plaster (K_1) = 0.72 W/mK
- Thermal conductivity of red-brick made of cement mortar (K_2) = 0.80 W/mK
- Thermal conductivity wall in-side cement plaster (K_3) = 0.72 W/mK

$$= 1/0.5945 = 1.682 \text{ (W/m}^2 \text{ K)}$$

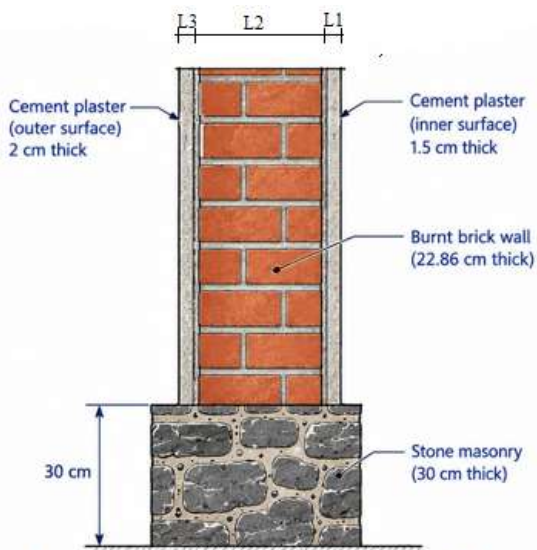


Fig-g: Details of Burnt-brick external wall in RCC-building

$$\text{Thermal resistance (R)} = \frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$$

$$R_1 = \frac{L_1}{K_1} = \frac{0.02}{0.72} = 0.027$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.2286}{0.80} = 0.285$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.02}{0.72} = 0.027$$

Total thermal resistance both side cement plastered brick wall

$$\text{For walls, } \frac{1}{f_i} = 0.125, \frac{1}{f_o} = 0.0515$$

$$(RT) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_1 + R_2 + R_3 = (0.0515 + 0.125) + 0.027 + 0.285 + 0.027 = 0.5155$$

$$\text{Thermal transmittance (U)} = \frac{1}{RT} = \frac{1}{0.5155} = 1.939 \text{ (W/m}^2 \text{ K)}$$

RCC Roof-slab:

The roof is made of RCC with a thickness of 12.5cm. The roof-top surface with cement plaster about 5cm thick and the inner roof-surface with cement plaster about 1.5cm thick and the other details are given in Fig-h.

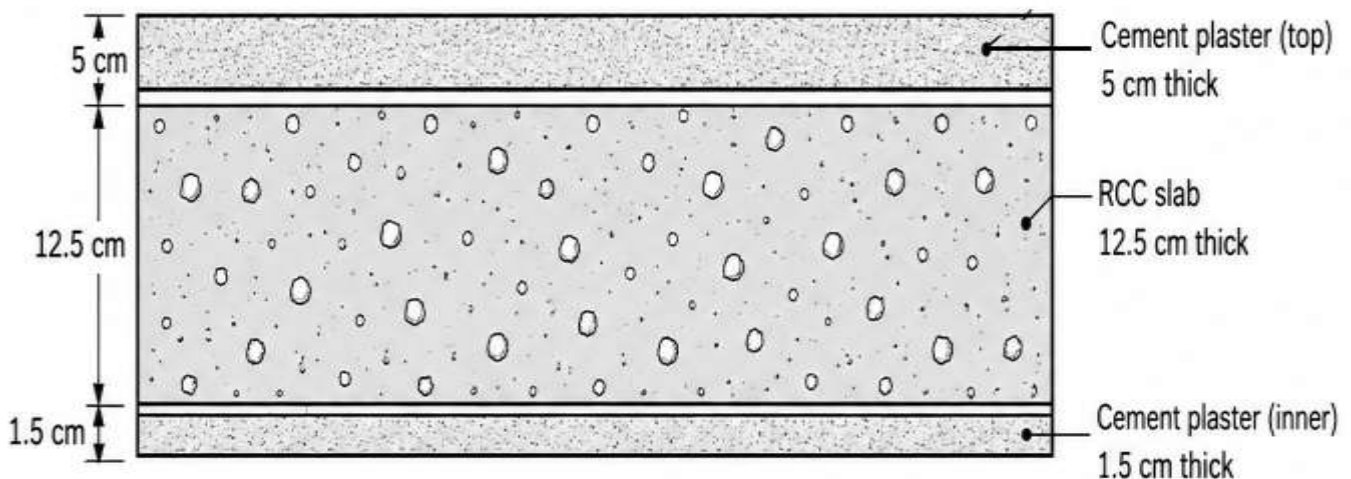


Fig-h: Details of RCC roof-slab for present modern building at Ramanapalle-village, Kadapa region A.P

Solution:

Thicknesses of materials are;

- Thickness of out-side roof-surface cement plaster (L_1) = 5cm = 0.05m
- Thickness of RCC slab (L_2) = 12.5cm = 0.125m
- Thickness of in-side ceiling surface cement plaster (L_3) = 1.5cm = 0.015m

Thermal conductivity of materials is;

oThermal conductivity wall outer cement plaster (K1) = 0.72 W/mK

oThermal conductivity of reinforced concrete slab (K2) = 2.30 W/mK

oThermal conductivity wall in-side cement plaster (K3) = 0.72 W/mK

Thermal resistance (R) = $\frac{\text{Thickness of material}}{\text{Thermal conductivity of material}}$

$$R_1 = \frac{L_1}{K_1} = \frac{0.05}{0.72} = 0.069$$

$$R_2 = \frac{L_2}{K_2} = \frac{0.125}{2.30} = 0.054$$

$$R_3 = \frac{L_3}{K_3} = \frac{0.015}{0.72} = 0.020$$

Total thermal resistance both side cement plastered brick wall

$$(R_T) = \left[\frac{1}{f_o} + \frac{1}{f_i} \right] + R_1 + R_2 + R_3 = (0.0515 + 0.171) + 0.069 + 0.054 + 0.020 = 0.3655$$

$$\text{Thermal transmittance (U)} = 1/R_T = 1/0.3655 = 2.735 \text{ (W/m}^2 \text{ K)}$$

For roofs, $\frac{1}{f_i} = 0.171, \frac{1}{f_o} = 0.0515$

VII. COMPARATIVE ANALYSIS

Comparative analysis in architectural research is a systematic method of comparing two or more buildings and the analysis process includes, settlements types, house types, construction materials and systems, thermal performance using the same set of parameters to identify. As per the title of the research paper, the author estimated overall heat-transfer coefficient of different walls and roof-system for both traditional Chowdu Midde and present RCC-building given in the tabular and the calculation are separately given.

Table-2: A comparative analysis of Chowdu Midde & RCC-building thermal performance in Ramanapalle

Table-2: A comparative analysis of Chowdu Midde & RCC-building thermal performance in Ramanapalle

Element Name	Component Type & Function	Cross section Description	Overall thicknes (m)	Thermal propertice of the layers								U-value ((W/m2K)
				Layer-1		Layer-2		Layer-3		Layer-4		
				L (m)	k-value (W/m K)	L (m)	k-value (W/m K)	L (m)	k-value (W/m K)	L (m)	k-value (W/m K)	
Wall Type-1	Black stone-wall (External-use)	0.73 thick Kadapa black stone masonry wall made of mud-mortar. Inside wall surface plastered with 2cm thick.	0.73m	0.73m	1.5	0.025	1.19	0	0	0	0	1.47
Wall Type-2	Mud-cob wall (External use)	0.55m thick masonry wall made of mud-cob. Both wall surfaces plaster with 2.5cm thick mud with cow-dung.	0.55m	0.025	0.81	0.55	0.85	0.025	0.81	0	0	1.13
Wall Type-3	Mud-cob wall (External use)	0.55m thick masonry mud-cob wall. External wall surface plaster with lime-morta about 3cm thick and internal wall surface plastery with mud cow-dung bout 2.5cm thick	0.55m	0.03	0.95	0.55	0.85	0.025	0.81	0	0	1.139
Wall Type-4	Red-brick wall (External use)	0.50m brick masonry wall made of burnt red-brick wall. External and internal wall surface plastered with lime-mortar about cm thick	0.5	0.03	0.95	0.55	1.0	0.03	0.95	0	0	1.35
Wall Type-5	Modern brick-wall (External use)	0.22m present brick masonry wall made of normal burnt brick with cement mortar. Outer wall plaster with cement mortar about 2cm thick, internal wall plaster with cement mortar about 1.2cm thick	0.22m	0.02	0.72	0.22	0.9	0.02	0.75	0	0	2.125
Roof Type-1	Chowdu Midde (Flat Roof)	It is a traditional flat roof made of local materials of sticks lattice, bamboo mat, Neem leaves and saline soil (chowdu matti).	0.105	0.05	0.35	0.005	0.055	0.01	0.35	0.04	0.15	0.827
Roof Type-2	Chowdu Midde (Flat Roof)	It is a traditional flat roof made of local wood reapers, burnt-brick wedgs and lime-mortar.	0.14m	0.03	0.7	0.09	0.6	0.02	0.11	0	0	1.682
Roof Type-3	RCC (Flat roof)	A RCC roof slab about 12.5cm. The slab top surface finished with cement plaster about 5cm thick and the ceiling surface finished with 1.2cm thick.	0.187m	0.05	0.72	0.125	2.3	0.012	0.72	0	0	2.41

VIII BEHAVIORAL ADAPTATION

User's behavioral adaptation is found to be essential for achieving thermal comfort in passive buildings [22]. The author has observed several behavioral adaptive actions the occupants have under taken in her many field study visits throughout the year. Important adaptation methods observed are 'clothing adaptation, moving to a shaded outdoor area during the period of discomfort, closing the roof lights/windows/doors, staying away from hot areas, and adaptively synchronizing the activities with the spatial environmental qualities. For example, the occupants have used well-lit semi outdoor areas for jobs that require higher illumination. They are found to adaptively balance the activities with the environmental characteristics of various spaces of the dwelling unit/outdoor areas. Similar observation is also made by Rijal el at research report done on 2002 [23]. In addition, special 'Pandiri' (canopy/pandala) erected in the front of the front-verandah as temporarily local wooden made structure roof covering with fresh green leaves like a wedding canopy during in summer by most of the occupants. This 'Pandiri' formed a shaded vestibule for front verandah as well as main-door and windows, giving the necessary thermal relief in summer from high-solar radiation and glare. In the study area, most of the behavioral adaptation achieved in-side the traditional house by application of the Chowde Midde because of the native materials and construction technics [24].

IX PRESENT DAY SCENARIO

The prototype houses shown in Fig-5 and Fig-6 are the result of many years of natural evolution and the passing down of traditional knowledge. These homes are built in a way that allows them to stay comfortable without needing any machines to cool or heat them during the hot summer or cold winter. However, in the last few decades, with the use of electric fans and air conditioners, the design of houses in Chowdu Middelu in Ramanapalle has changed quickly from the traditional style to modern reinforced concrete buildings.

People are trying out large thermal mass in their homes to build faster and use less space. The walls are now usually 22cm thick or made of slender bricks with mud or cement mortar. The roofs are either made of RCC, which is between 12.5 to 15cm thick, and have no insulation on top, or they use galvanized iron or asbestos sheets if the person can't afford the RCC option. With the use of electric fans, many activities that used to take place

in semi-outdoor spaces, such as cleaning grain, resting, and reading, are now done inside homes. Because of this, windows have become much bigger, letting in more light and heat. Unfortunately, not only Ramanapalle but also other villages in Kadapa district are in areas that are not a priority for electricity supply, and power is especially scarce during the summer. As expected, people living in houses with concrete roofs feel more discomfort due to heat.

Moreover, the villagers see RCC-roofed houses as more socially respected and modern compared to traditional tiled houses, because they are influenced by many images from cities. Surprisingly, young people who live in houses with concrete roofs are also preferred in marriage.

Because of this, local buildings are being replaced by modern designs that use electrical systems for comfort. The warm, small groups of homes that were built to fit with people's daily lives are turning into separate, modern houses. Architecture and ways people live that used to be closely connected to the climate and traditions are slowly changing into styles that ignore the environment and local customs. This same issue is mentioned by Upadhyay et al [28] and Hanaoka et al [29]. With less support, the traditional skills for making roofs are almost disappearing. Some villagers are now moving to other jobs that make more money. Because of this, there is a shrinking supply and demand for traditional roofing. The main purpose of shelter, which acts like our third skin by keeping us warm, is becoming less important as buildings become lighter and simpler.

As the research author try to find a good balance between modern ideas and traditional values, the success of traditional settlements offers important lessons for today's designers, architects, and planners. Keeping traditions alive needs careful planning, clear design rules, and guidelines. It also requires setting up a code of practice to manage how traditions are handled, no matter if the technology is new or old. Only in this way can the new buildings we create stay closely connected to the local climate, environment, and culture.

X. CONCLUSIONS

Architecture and climate form an inseparable bond in any traditional shelter form. Learning them in detail helps to building designers plan sustainable and eco-friendly

settlements mostly in rural area in future, especially in the wake of the present energy debate. The vernacular settlement of Ramanapalle in the hot semi-arid climatic zone in Kadapa district of Andhra Pradesh has been studied and documented as part of a large development study. The data has been studied and analyzed keeping in mind the aspects of architectural typology and the climate appropriateness of various features of the traditional building and the settlement. Following are the conclusions:

1. The traditional buildings in Ramanapalle are very much influenced by the climate, showing how different factors like weather and earth conditions, along with religion, social beliefs, money matters, technology, and traditional government rules, all play a part in shaping them.

2. The traditional houses in Ramanapalle are designed to handle the hot, dry summers. The area has developed naturally on flat land made of salty soil, shaped by the local geography. Because there isn't much groundwater and the land isn't well covered, there are hot winds during dry periods and hot summers. These hot winds can be controlled by narrow streets, traditional outer walls, and roofs made from local materials.

3. Group of close-built homes are arranged naturally along the narrow streets and alleys. These clusters make up a big part of the settlement and help protect the walls and the ground from bright sunlight and uncomfortable glare.

4. The traditional house is made of very thick material and has a lot of thermal mass. It features thick walls, heavy roofs, and small windows shaded with front deep verandah. The design uses local methods and materials such as stone, brick, wood mud and lime mortar

5. Many types of houses are identified, and their designs differ in size, shape, level of detail, and how they respond to the climate. These houses work well with the way people use the space. The people living there adjust their activities to match the qualities of the space around them.

6. For the past few decades, the way buildings look, the architecture, and the attitudes of people in Ramanapalle have been slowly changing. This is happening because the old flat-roofed houses are getting damaged, and the top roof soil frequently replace. These changes are influenced by social and economic factors, and people are now using electric systems to

stay comfortable during different seasons. The new generation are felt to construct honored to have concrete houses as more valuable because they are associated with modern ideas brought in from outside. and they consider them a sign of success, even though living in them can make them feel hotter and less comfortable.

7. Once highly climate appropriate architecture and behavioral patterns in Ramanapalle are slowly getting changed into architecture and attitudes that are irreverent to climate and context. Most of the elders and 60-70% of young generation want to continue with the house with new design of the flat roof by replacing dantelu (wooden beams, rafters) with pre-cast or steel section dantelu.

REFERENCES

1. Lisa Heschong (1979): Thermal delight in architecture. Cambridge, MA: The MIT Press;1979.
2. M.A.Eben Saleh (1999): Al-Alkhalaf: The evolution of the urban built-form of a traditional settlement in Southwestern Saudi Arabia. Volume 34, Issue 6, November 1999, Pages 649-669. [https://doi.org/10.1016/S0360-1323\(98\)00047-X](https://doi.org/10.1016/S0360-1323(98)00047-X)
3. A.S. Dili, M.A. Naseer & T. Z. Varghese (2010): Passive control methods of Kerala traditional architecture for a comfortable indoor environment: Comparative investigation during various periods of rainy season. Volume 45, Issue 10, October 2010, Pages 2218-2230. <https://doi.org/10.1016/j.buildenv.2010.04.002>
4. MS Sözen, GZ Gedik GZ (2007): Evaluation of traditional architecture in terms of building physics: old Diyarbakır houses. Building and Environment. Volume 42, Issue 4, April 2007, Pages 1810-1816. <https://doi.org/10.1016/j.buildenv.2006.01.019>
5. VA Maria (2009): Evaluation of a sustainable Greek vernacular settlement and its landscape: architectural typology and building physics. Building and Environment. Volume 44, Issue 6, June 2009, Pages 1095-1106. <https://doi.org/10.1016/j.buildenv.2008.05.026>
6. Ardeshir Mahdavi, Satish Kumar (1996): Implications of indoor climate control for comfort, energy and environment. Energy and Buildings. Volume 24, Issue 3, Pages 167-243.
7. Sue Roaf, David Crichton & Fergus Nicol (2005): Adapting buildings and cities for climate change a 21st

- century survival guide, 2nd Edition, Oxford: Architectural Press; 2005.
8. S Bin, M Evans (2008): Building energy codes in APP Countries. 5th meeting, June 23, 2008, Seoul, Korea. APP Building and Appliances Task Force; 2008.
 9. V Olgyay (1963): Design with Climate. Princeton University Press, Princeton, NJ
 10. OH Koenigsberger, TG Ingersoll, A Mayhew (1974): Manual of tropical housing and building. [By] Otto H. Koenigsberger, TG Ingersoll, Alan Mayhew, SV Szokolay
 11. <https://kadapa.ap.gov.in/villages>: Government of Andhra Pradesh YSR Kadapa District Village record
 12. <https://kadapa.ap.gov.in/gram-panchayat>: Government of Andhra Pradesh Grama Panchayat record
 13. <https://www.census2011/chennur-ysr-andhra-pradesh-tmyl>: Chennur Mandal YSR (2011): Chennu Mandal Census 2011 village-level population records including Ramanapalle, Bayanapalle and other 11 villages
 14. ICOMOS (2003). Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage
 15. Government of Andhra Pradesh – About YSR Kadapa: general tropical climate and annual temperature information
 16. Madavi Indraganti, M. (2010). “Understanding the climate sensitive architecture of Marikal, a village in Telangana region in Andhra Pradesh, India.” Building and Environment, 45(12).
 17. Geological Survey of India (GSI): geological and geomorphological information on the Cuddapah Basin and Andhra Pradesh.
 18. INTACH Architectural Heritage. Traditional Settlement – Gandikota Village, Kadapa District, Andhra Pradesh. Documented example of traditional Rayalaseema settlement morphology.
 19. Mukherjee, M. (2023), Unit-13: Structure and Morphology of Rural Settlements. Indira Gandhi National Open University (IGNOU). The unit discusses rural morphology, street patterns, dwelling arrangement and physical, socio-cultural and economic determinants.
 20. Mukharjee M (2023), Unit 14: Rural Settlements, covering settlement patterns and rural morphology in the Indian context
 21. Karve (1957): THE INDIAN VILLAGE. Vol. 18, January 1957, TARAPOREWALA MEMORIAL VOLUME. <https://www.jstor.org/stable/i40112735>
 22. Petta Eswara Rao (2024): Glimpses of Kadapa Traditional Religious Architecture. Paper presented at the International Conference on Religious Architecture held on 29-30-2024 NIT Patna, India.
 23. CS Tarun, J Vijayalaxmi (2025): Indoor Thermal Performance of Roof using Vernacular Materials in Hot Semi-arid regions.
 24. Madavi Indraganti (2010): Behavioral adaptation and the use of environmental controls for thermal comfort in apartments in India. Energy and Buildings. Volume 42, Issue 7, Pages 967-1164. 10.1016/j.enbuild.2010.01.014
 25. HB Rijal HB, H Yoshida (2002): Comparison of summer and winter thermal environment in traditional vernacular houses in several areas of Nepal. Advances in Building Technology. Volume II, Pages 1359-1366. 10.1016/B978-008044100-9/50169-8
 26. Tarun, C. S., & Jeyasingh, V. (2025). “Indoor Thermal Performance of Roof Using Vernacular Material in Hot Semi-arid Region.” Sustainable Building Performance, pp. 59–74. The study specifically examines vernacular construction using Kadapa stone and lime roofing in the hot semi-arid Kadapa region.
 27. B Givoni (1998): Climate Considerations in Building and Urban Design. John Wiley & Sons.
 28. AM Upadhya, H Yoshida, HB Rijal (2006): Climate responsive building design in Kathmandu valley. Journal of Asian Architecture and Building Engineering.
 29. S Hanaoka, HB Bahadur, S Hata (2009): Changes and improvements to traditional vernacular houses in a mountain area of Nepal. In: Proceedings of the 3rd International Conference on Environmentally Sustainable Development, 16-18 Aug. 2009, Pakistan.