Sustainable Design Checklist for USA Koppen Zone A

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Prepared for:

Auroma Synergy

ChinnaKottakuppam, Tamil Nadu

Prepared by:

cBalance Solutions Private Limited

1. Introduction – Koppen Zone A

Climate description: Tropical Climate

Location: South Central & Southern

Tropical moist climates extend northward and southward from the equator to about 15 to 25 degrees of latitude. In these climates all months have average temperatures greater than 18 degrees Celsius. Annual precipitation is greater than 1500 mm. Three minor Köppen climate types exist in the A group and their designation is based on seasonal distribution of rainfall. **Af** or tropical wet is a tropical climate where precipitation occurs all year long. Monthly temperature variations in this climate are less than 3 degrees Celsius. Because of intense surface heating and high humidity, cumulus and cumulonimbus clouds form early in the afternoons almost every day. Daily highs are about 32 degrees Celsius while night-time temperatures average 22 degrees Celsius. **Am** is a tropical monsoon climate. Annual rainfall is equal to or greater than Af, but falls in the 7 to 9 hottest months. During the dry season very little rainfall occurs. The tropical wet and dry or savanna or **Aw** has an extended dry season during winter. Precipitation during the wet season is usually less than 1000 millimeters and only during the summer season[1].

[1] Auxiliary Program - Energy Plus

2. Sustainable Residential Design Checklist

2.1 Thermal Comfort Requirements

- ☐ Use CBE thermal comfort tool[2] to predict the thermal comfort requirement
- ☐ Maintain indoor humidity in the range of 30% to 60% by controlled mechanical ventilation, mechanical cooling, or dehumidification
- ☐ Select low-VOC paints, finishes, varnishes, and adhesives whenever possible

2.2 Building Envelope & its Components

2.2.1 Daylighting

- ☐ Calculate the WWR for a typical built space using analytical method or software modelling and adjust according to the energy building codes
- ☐ Perform daylighting feasibility analysis
  - ➢ Make a preliminary glazing selection and note the visible transmittance (VT)
  - ➢ Estimate the obstruction factor (OF)
  - ➢ Calculate the feasibility factor (FF)
    FF = WWR * VT * OF
  - ➢ If FF ≥ 0.25, then daylighting has the potential for significant energy savings. If FF < 0.25, then consider removing obstructions, increasing window area, or increasing VT
- ☐ Integrate daylighting improvement feature in envelope - deep reveals, splayed reveals, exterior fins

2.2.2 Form, Orientation & Space Planning

- ☐ Shape: Select a square shape or as close to circular to minimize perimeter-to-area ratio
- ☐ Height: to reduce vertical exposure to sunlight and maximize rooftop solar energy and rainwater harvesting area
- ☐ Orientation: reduce exposure of east and west surfaces to morning/evening sun respectively; longer facades facing south and north
- ☐ Locate air-conditioned zones using Mahoney's table; buffer zones on the periphery
- ☐ Locate outdoor/ units/heat rejection units in shaded areas/away from direct solar radiation
- ☐ Integrate self-shading: Balconies, deep reveals or arcades
- ☐ Integrate passive shading elements: Overhangs, louvers, fins, awnings and light shelves. Whether the chosen shading element and its dimensions are appropriate or not, can be validated using the shading and daylight analysis tool on http://andrewmarsh.com/software/

2.2.3 Openings

- ☐ Design the windows higher to deepen the daylighting zone
- ☐ Treat each window orientation differently for best results

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2 CBE Thermal Comfort Tool Link - http://comfort.cbe.berkeley.edu/

- ➢ North: High quality consistent daylight with minimal heat gains, but thermal loss during heating conditions and associated comfort problems. Shading possibly needed only for early morning and late afternoon
- ➢ South: Good access to strong illumination (the original source), although varies through the day. Shading is "easy"
- ➢ East and West: Shading is difficult. Shading is critical for comfort on both sides and heat gain too, especially on the west. Windows facing generally north and south create the fewest problems

- Use a horizontal form for south windows
- Use a vertical form on east and west windows
- Incorporate appropriate shading devices (vertical & horizontal) using standalone tools or Energy-Plus based software
  - ➢ If the sun passes high in the sky across an opening, a horizontal shading device is to be used to exclude solar radiation. This is effective for north- and south-facing openings
  - ➢ If the sun passes low in the sky to shine into an opening, a vertical shading device is to be used to exclude solar radiation. This is effective for east- and west-facing openings
- Position windows to direct light onto the ceiling – e.g. light-shelf
- Size the windows and select glazing at the same time
- Choose a spectrally selective glazing with moderate visible transmittance for glare control (50-70% is a good starting point, depending on visual tasks, window size and glare sensitivity)
- Maintain the balance between glare and useful light using standalone tool or modelling software like COMFEN[3]

2.2.4 Walls

- Incorporate thermal mass/ insulations in design - If diurnal summer temperatures span human thermal comfort zone, use thermal mass, else insulation
- Design thermal mass with adequate decrement/dampening and time-lag factor:
  - o Use following formula for calculating appropriate wall-thickness

Wall thickness (m) = $$\frac{-b+\sqrt{b^2-4ac}}{2a}$$

where:

b = $(I_{sol} \times A_{wall} - TR_{air-con} \times 3517) \times T_{daylight-hrs} \times 3.6$

where:

$I_{sol} = Solar\ Radiation\ \left(\frac{W}{m^2}\right)$

$A_{wall} = Total\ Solar - Exposed\ Wall\ Area\ (m^2)$

$TR_{air-con} = Target\ Air - Conditioning\ Load\ (TR)$

$T_{daylight-hours} = Avg.Daily\ Hours\ of\ Solar\ Exposure\ (hours)$

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[3] COMFEN tool link: https://windows.lbl.gov/software/comfen

a = $\left(Th_{cap} \times A_{wall} \times \left(\frac{T_{sol-air}+T_{in}}{2}\right) - T_{morn.}\right)$

where:

$Th_{cap} = Thermal\ Capacity\ of\ Wall\ Material\ \left(\frac{kJ}{m^3.°C}\right)$

$A_{wall} = Total\ Solar - Exposed\ Wall\ Area\ (m^2)$

$T_{in} = Avg.Indoor\ Air\ Temprature$ (°C)

$T_{morn} = Morning\ Air\ Temprature\ (Outside)$ (°C)

$T_{sol-air} = Sol - Air\ Temparature$ (°C) = $T_{out} + \frac{I_{sol} \times Ab}{U_{sc}}$

where:

$T_{out} = Avg.Outside\ Air\ Temprature$ (°C)

$I_{sol} = Solar\ Radiation\ \left(\frac{W}{m^2}\right)$

$Ab = Solar\ Absroptance\ (diminsionless)$

$U_{SC} = Outside\ Wall\ Surface\ Conductance\ (\frac{W}{m^2.°C})$

c = ($\lambda \times A_{wall} \times (T_{sol-air} - T_{in}) \times T_{daylight-hrs} \times 3.6$

where:

$\lambda = Thermal\ Conductivity\ \left(\frac{W}{m.°C}\right)$

$T_{sol-air} = Sol - Air\ Temparature$ (°C)

$A_{wall} = Total\ Solar - Exposed\ Wall\ Area\ (m^2)$

$T_{in} = Avg.Indoor\ Air\ Temprature$ (°C)

$T_{daylight-hours} = Avg.Daily\ Hours\ of\ Solar\ Exposure\ (hours)$

- Select material and design exterior wall insulation thickness based on ASHRAE Adaptive Comfort Model or desired Thermal Heat Index reduction
- Keep east and west facing walls as short as possible
- Keep the outer surface of walls light in colour to reduce the transfer of heat
- Don’t use kraft-faced or foil-faced insulation in framed or masonry walls
- Select advanced framing techniques
    - Two Foot Module Design
    - Frame 24-Inch on Centre
    - Align Framing Members and Use a Single Top Plate
    - Size Headers for Actual Loading Conditions
    - Use Ladder Framing
    - Use Two Stud Corners
    - Eliminate Redundant Floor Joists
    - Use 2*3 Frame for Partitions

2.2.5 Roofs/Attic

- Design composite roofs in which the roof and ceiling are made of lightweight materials
- Orient roofs towards the prevailing breezes and avoid obstructions to the air movement
- Use domed or pitched roof (preferably round form)
- Design ventilation openings between roof and ceiling
- Design pitched roofs with large overhanging eaves in areas where rainfall is heavy

- Design timer-based external radiant barrier (low emissivity) for attics/roofs with low thermal mass
- If Radiant-Barrier not possible, design cool-roof using standalone tools or Energy-Plus based software
- Select material and design roof insulation thickness based on ASHRAE Adaptive Comfort Model or desired Thermal Heat Index reduction. Adaptive model relates indoor design temperatures or acceptable temperature ranges to outdoor meteorological or climatological parameters. ASHRAE Adaptive Comfort Model equation is -

$$T_{oc} = 18.9 + 0.225 * T_{out}$$

where T_{oc} is operative comfort temperature and T_{out} is mean outside monthly temperature of the month in °C.

2.2.6 Floors

- Design ground floor about 50-60 cm to profit from the cooling from the vegetation below, however, if the wind exposure is found more crucial, or maybe for functional reasons, the floor could be increased to a full storey height
- Design the floor with lightweight construction
- Provide gaps between floorboards to improve ventilation
- Design built-in ducts, if there is a need of a solid floor, such as a hollow concrete slab with the double purpose of reduction of thermal storage capacity and providing ventilation with natural cooling

2.3 Thermal Properties of Building Materials

- Use reflective outer roof surfaces to reduce heat gains
- Select floor materials with the low thermal storage properties
- Select the windows with the following U values and SHGC:

Table 1 Permissible U value and SHGC value of Windows

Climate Zone	U Value (btu/hr.sq.ft. F)	SHGC
South Central	≤ 0.30	≤0.25
Southern	≤ 0.40	≤0.25

(Source: Building America Best Practices Series Volume 15)

- Select the skylight assemblies with the following U values and SHGC:

Table 2 Permissible U value and SHGC value of Skylights Assemblies

Climate Zone	U Value (btu/hr.sq.ft. F)	SHGC
South Central	≤ 0.53	≤0.28
Southern	≤ 0.60	≤0.28

(Source: Building America Best Practices Series Volume 15)

- Select the Doors with the following U values and SHGC:

Table 3 Permissible U value and SHGC value of Doors

Door Glazing Level	U Value (btu/hr.sq.ft. F)	SHGC
Opaque	≤ 0.17	No Rating
≤ ½ lite	≤ 0.25	≤0.25
> ½ lite	≤ 0.25	≤0.25

(Source: Building America Best Practices Series Volume 15)

- Select the Insulation materials with following R values:

Table 4 R value of a different insultation materials

Insulating Material	Specification	R Value - Avg. R value per inch
Fiberglass	Unfaced batt, standard density	R-2.9 to R-3.8
	Unfaced batt, high density	R-3.7 to R-4.3
	Blown fiberglass	R-2.2 to R-2.7
Expanded Polystyrene (EPS)	Rigid foam board	R-3 to R-4
	Beads	R-2.3
Extruded Polystyrene (XPS)	Rigid foam board	R-5
Polyisocyanurate	Rigid board	R-5.6 to R-8
	With foil facing	R-7.1 to R-8.7
Polyurethane	Spray foam or foam board	R-7 to R-9
	Foam board with foil facing	R-7.1 to R-8.7
	Soy-based polyurethane spray foam	R-3.7
Others	Cellulose, blown	R-3.6 to 3.8
	Mineral wool, rock or slag, batt or loose	R-3.7
	Cotton batt	R-3.4
	Sheep’s wool batt	R-3.5
	Strawbale	R-2.4
	Plastic PET	R-3.8 to R-4.3

(Source: Building America Best Practices Series Volume 15)

2.3 Natural Ventilation, Cooling and Heating

2.3.1 Natural Ventilation and Passive Cooling Techniques

- Design for minimum ventilation requirements based on ASHRAE Standards

Table 5 Common ventilation requirements for fresh air and odour removal

Space and Activities	Ventilation Rate (ACH)
Light office work – Occupancy density: 5 m^2/person	1.2 – 2.0
Light office work – Occupancy density: 10 m^2/person	0.4 – 0.7
Light office work – Occupancy density: 15 m^2/person	0.1 – 0.25
WC (4.5 m^3)	13
WC and Bathroom (12 m^3)	9
Kitchen (approx. 10 m^2) to prevent condensation	
Kitchen with non-absorbent surfaces:	
Gas cooking	13
Electric cooking	9
Kitchen with absorbent surfaces:	
Gas cooking	5.5
Electric cooking	2.7
Whole Building	
Whole building Minimum	1
To avoid odours and stuffiness	2
To avoid condensation	4

(Source: Stay cool by Holger Koch-Nielsen)

- Openings should be placed on opposing facades to facilitate cross-ventilation of rooms
- Design larger openings on leeward side and smaller windows on windward side
- Design openings to create a difference in height between the inlet and outlet openings
- Design windows at body-level height
- Design a passive downdraft cooling system
- Design stack ventilation mechanism to facilitate internal ventilation
- Include wind tower/ wind catcher in design
- Design a courtyard as per the availability of space
- Look to design external structures, such as walls adjacent to buildings, hedging, etc., to alter the direction of winds, deflect undesired winds or change the velocity of winds

2.3.2 Active Cooling and Heating Techniques

- Design a structure cooling system to reduce the solar heat gain from the roof
- Design an indirect evaporative cooling with conventional air conditioning system using energy plus software or standalone tool
- Alternatively, design a radiant cooling with conventional air conditioning system using energy plus software or standalone tool
- Select central air conditioners at a minimum 13 SEER- Seasonal Energy Efficiency Ratio (10 EER - Energy Efficiency Ratio) for cooling
- Use alternative technologies like on-demand gas or electric water heaters, solar thermal water heaters, and air-source heat pumps for water heating
- Select heat pumps at a minimum of 7.7 HSPF- Heating Seasonal Performance Factor for heating
- Don’t design ducts on exterior walls

- Design insulating ducts in unconditioned spaces. Insulate supply ducts to R-8 minimum and return ducts to R-4 minimum
- Design insulating ducts in conditioned space to R-8 for supply and R-4 for return ducts to avoid condensation formation
- Select Energy Star - qualified equipment
- Calculate peak cooling/heating load and energy use using Energy Plus based software
- Calculate the annual energy saved with improved design elements
- Select an effective energy management system to optimize building operation and tie together all HVAC, lighting and automated shading controls

2.5 Lighting

- Make daylight integration part of lighting design from the beginning
- Choose direct/indirect lighting to avoid glare and match daylight distribution
- Plan fixture layout to match daylighting distribution using daylighting simulations
- Select energy efficient lighting systems – LED or CFL
- Select light coloured internal finishes to improve lighting conditions
- Select lighting and occupancy sensors