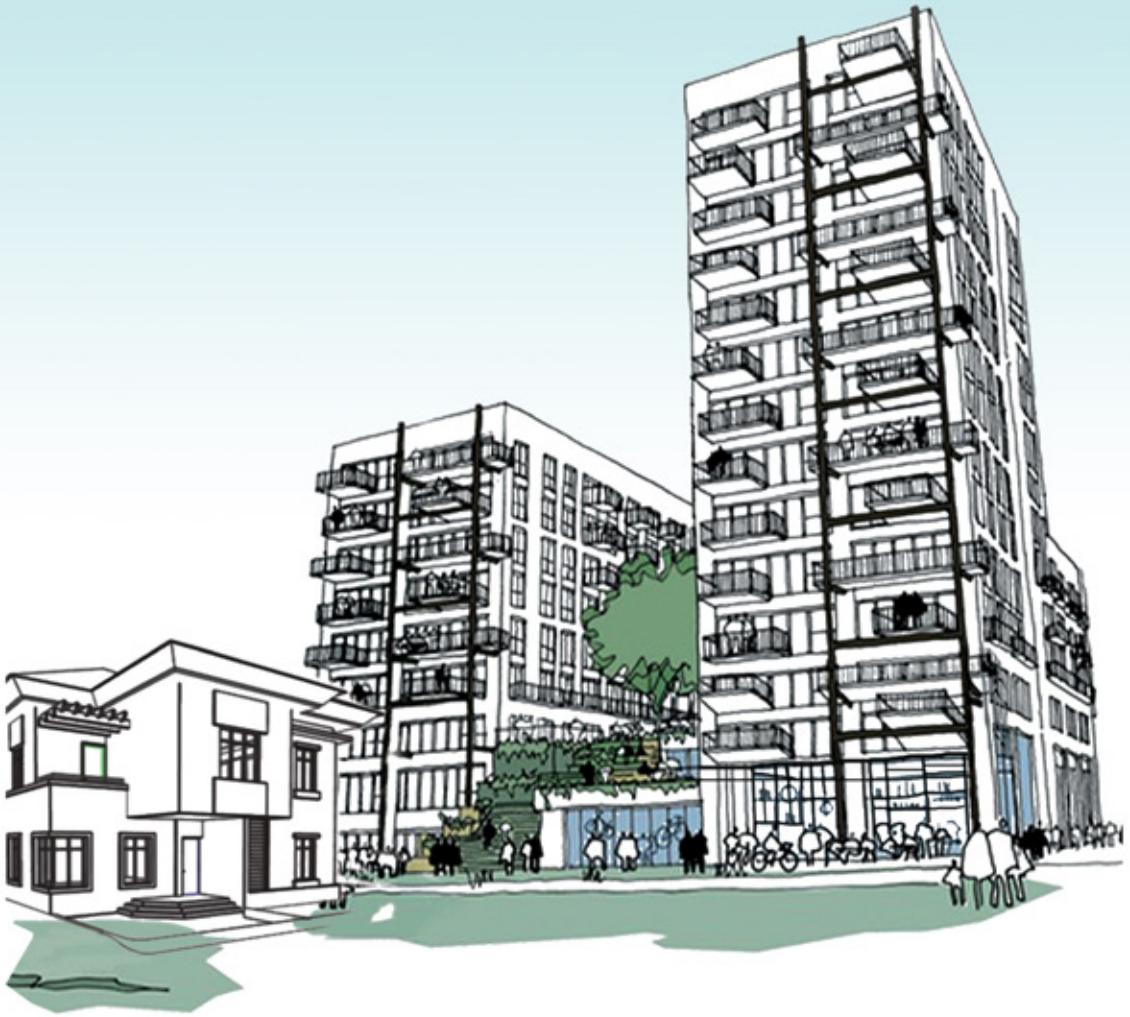
TOWARDS ECO-NIWAS SAMHITA IMPLEMENTATION IN RAJASTHAN: BUILDING ENVELOPE SOLUTION SETS

FOR EXTERNAL WALLS, ROOF, WINDOW SHADING, AND GLAZING



RRECL

BEEP
BUILDING ENERGY EFFICIENCY PROJECT

Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets

For External Walls, Roof, Window Shading, And Glazing

RAJASTHAN

BUREAU OF ENERGY EFFICIENCY (BEE)
(Ministry of Power, Government of India)
Website: www.beeindia.gov.in

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Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets

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The Government of India launched Eco-Niwas Samhita (ENS) 2018 (Part -1 Building Envelope), which is the energy conservation building code for residential buildings.

To facilitate the implementation of the ENS at the national level and provide assistance to concerned stakeholders, a reference booklet titled Building Envelope Solution Sets (v 1.0) for Eco-Niwas Samhita 2018 was developed and launched by the Bureau of Energy Efficiency (BEE) in December 2021. On similar grounds, through a detailed market survey for Rajasthan, considering region-specific construction practices and local construction materials, state-specific solutions have been developed to meet the ENS compliance requirements.

This publication 'Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets' is a ready reckoner to get the building envelope solutions for meeting ENS compliance. Shri Anil Dhaka, Managing Director, RRECL, provided full support and guidance to the core development team.

The core development team of the Indo-Swiss Building Energy Efficiency Project (BEEP) along with their local agency had worked hard to ensure that the content presented in the booklet is of top quality and relevant to the building construction industry.

Jaipur

5th August 2022

Sh. T. Ravikanth, IAS

CMD, Rajasthan Rajya Vidyut Prasaran Nigam Limited (RVPN) &
Chairman, Rajasthan Renewable Energy Corporation Limited, (RRECL) Jaipur

BUREAU OF ENERGY EFFICIENCY (BEE)
(Ministry of Power, Government of India)
Website: www.beeindia.gov.in

SAURABH DIDDI

Director, Bureau of Energy Efficiency

The Bureau of Energy Efficiency (BEE) has a multi-pronged approach to achieve thermally comfortable and energy efficient buildings in the country. The approach consists of framing regulations in the form of Energy Conservation Building Codes, market transformation through Appliances and Building Labelling Programme, and awareness creation and capacity building.

As far as regulations are concerned, BEE has developed Energy Conservation Building Code (ECBC) for commercial buildings. The recent version of ECBC was issued in 2021. Given the anticipated rapid growth in residential building stock across India and the consequent opportunities as well as the necessity for energy conservation in this sector, BEE had launched the Energy Conservation Building Code for Residential buildings in 2018 called "Eco-Niwas Samhita (ENS)" .

The code defines provisions for building envelope to reduce heat gain/loss and improve natural ventilation and daylighting potential. To facilitate the implementation of the ENS and provide assistance to concerned stakeholders, a reference booklet titled, 'Building Envelope Solution Sets (v 1.0) for Eco-Niwas Samhita 2018' was developed. This booklet provides ready solutions on the basis of real-life practices to meet building envelope-provisions of ENS. Further, to accelerate the work in Rajasthan, a state-specific building envelope solution sets have been developed as 'Towards Eco-Niwas Samhita- Implementation in Rajasthan: Building Envelope Solution Sets'. This was prepared based on a market survey for the state to include local material and construction practice. In other words, the focus of state specific solution sets is on making the building envelope design energy efficient and thermally comfortable by meeting the ENS provisions for Residential Envelope Transmittance Value (RETV) and roof compliance.

This publication has been developed in close consultation with the local building sector agencies and professionals. I hope this publication will play an important role towards ENS implantation in the Rajasthan state and inspire other states to work in the same direction.

New Delhi
5th August 2022

Saurabh Diddi
Director, Bureau of Energy Efficiency

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

ANAND SHUKLA
Senior Advisor
Swiss Agency for Development and Cooperation

The Indo-Swiss Building Energy Efficiency Project (BEEP) has been a landmark bilateral cooperation project between the governments of Switzerland and India since 2011. Together with Swiss and Indian partners, the Swiss Agency for Development and Cooperation (SDC) has supported BEEP to build on Switzerland's four decades of experience to co-develop knowledge and expertise on energy efficient building design, technologies, and policies in India.

The development of the Eco-Niwas Samhita (ENS) 2018 (Part 1 – Building Envelope) was an important milestone in that direction. To help meet the code requirements, a ready reckoner set of national building envelope solution sets was developed and launched in December 2021 considering the real-life practice and projects implemented in the past. To facilitate the implementation of ENS 2018 in the state of Rajasthan and to cater to region-specific requirements, state-specific building envelope solution sets have been developed titled, 'Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets'.

The Rajasthan Building Envelope Solution Sets (2022) have been prepared after delving into practical and directly implementable solutions drawn through a market survey conducted in the state. The primary objective of this publication is to help building designers in the adoption of ENS 2018 at the state level.

This publication serves as a supplementing document that will help achieve the Residential Envelope Transmittance Value (RETV) and roof provisions for building envelope as per ENS 2018 in the state of Rajasthan. It is prepared in such a manner that it will help users to make an informed choice on how best to meet building envelope-related code provisions in Rajasthan.

The success of any development cooperation project lies in its effective implementation on the ground. Building practitioners hold the key to the successful implementation and adoption of a code, as they also understand the local climatic conditions and preferences. BEEP has been successfully supporting the Bureau of Energy Efficiency (BEE) in the implementation of ENS in other states such as Gujarat and Andhra Pradesh. We hope the practitioners in Rajasthan will find this document useful to the cause that we are all wedded to, i.e., to reduce energy consumption in the residential building sector in India and achieve thermal comfort.

New Delhi
5th August 2022

Anand Shukla
Senior Advisor
Swiss Agency for Development and Cooperation

MR. ANIL DHAKA, IRS

Managing Director

The residential building sector is slated to increase by 2.5 times (in terms of floor area) by 2030 from the 2017 level. In 2018, the Bureau of Energy Efficiency (BEE) – under the Ministry of Power, Government of India – launched the second version of the Energy Conservation Building Code (ECBC) for new 'commercial' buildings to establish minimum energy performance standards for new, commercial buildings. In continuation of the larger vision of energy conservation, and intending to improve thermal comfort and energy conservation in residential buildings, the BEE came up with the Energy Conservation Code for Residential Buildings, Eco-Niwas Samhita (ENS), Part I- Building Envelope in 2018. To accelerate the work in Rajasthan and cater to the region-specific materials used for construction, state-specific building envelope solution sets have been developed based on a market survey titled 'Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets'.

In other words, the focus of state-specific solution sets presented in this publication is on making the building envelope design thermally comfortable and energy efficient by evaluating the Residential Envelope Transmittance Value (RETV) of buildings and suggesting practical solutions for building envelope components (which includes windows, walls, shading, and roof) to achieve ENS compliance in this state. RRECL would like to appreciate the Swiss Agency for Development and Cooperation, BEEP's partner organizations in Switzerland (Effin'art Sarl) and in India (Greentech Knowledge Solutions Pvt. Ltd), BEE officials, and all other stakeholders who have played pivotal roles in bringing the issue of building energy efficiency to the mainstream.

I am sure this document will be of immense value to architects, engineers, and developers in the building/construction sector in Rajasthan.

Jaipur

5th August 2022

Mr. Anil Dhaka, IRS

Managing Director

Rajasthan Renewable Energy Corporation Limited, (RRECL) Jaipur

CONTEXT

In India, residential buildings consumed around 255 TWh of electricity in 2017 and it is expected to increase by 3 folds by 2030. Increased adoption of air-conditioning in residential buildings is one of the key reasons for this growth. Residential buildings will become the largest end-user of electricity in the country accounting for 38% of the total electricity consumption by 2030. The major drivers for the growing residential sector are increasing new construction, and rising demand in the housing sector especially in the affordable housing segment. (Niti Aayog, 2015)

The Ministry of Power, Government of India, has launched Eco-Niwas Samhita (ENS) 2018 or Energy Conservation Building Code for Residential Buildings (ECBC-R), Part I: Building Envelope on 14 December 2018. The code defines provision for building envelope to reduce heat gain/loss and improve natural ventilation and daylighting potential. A national building envelope solution set document was developed which was ready reckoner set of solutions made to facilitate the implementation of the code as per CPWD's building schedule of rates 2019. To cater to region specific requirements for implementation of ENS 2018, this document is prepared that contains solution sets specific to the state of Rajasthan to help meet the code requirements on reducing heat gains from building envelope. It contains details of external wall construction, roof construction, and window shading to help meet the Residential Envelope Transmittance Value (RETV) and the roof U-value requirements of the code.

Rajasthan is located in the north-west of India. As per the National Building Code (NBC) 2016 climate classification (National Building Code of India, 2016) majority of Rajasthan is classified as Hot and Dry. The state's climate ranges from arid to semi-arid. Summer generally sets in around March. The temperature starts rising from the month of April and continues till June. Rajasthan experiences low and variable rainfall, making it vulnerable to drought.

Rajasthan's population is estimated to be approximately 7.29 crore. (Unique Identification Aaadhar India, 2021). This equates to about 6% of the Indian population. According to the latest Census, Rajasthan's population is growing at a pace of roughly 2.1 percent each year. Additionally, according to the 2011 Census, 24.87 percent of Rajasthan's population lives in urban areas. The total housing shortfall in Rajasthan has increased considerably in the last decade (around 17 percent on average). Out of which majority of shortage is found to be in the EWS/LIG category.

The affordable housing segment is seeing a boom in construction due to the impetus from PMAY (Pradhan Mantri Awas Yojana). This has also led to the introduction of innovative and faster construction technology, where the key focus is the time-cost economy, adaptability, sustainability, and quality assurance. In this process, alternative construction materials like EPS panels, AAC blocks, Fly ash blocks, etc. have become potential construction materials. Out of 2.11 lacs houses, construction work has started for around 57% of houses and around 41% of the houses are completed. Thus, with the amount of ongoing and proposed construction the total electricity consumption is projected to increase significantly.

HOW THIS DOCUMENT CAN HELP IN MEETING ENS PROVISIONS?

The Eco-Niwas Samhita 2018 or Energy Conservation Building Code for residential buildings (ECBC-R), Part I: Building Envelope defines the provisions for the following:

1. for natural ventilation potential[1];
2. for daylight potential[2];
3. to limit heat gain/loss from the roof;
4. to limit heat gain from the building envelope (excluding roof) in four climatic zones (composite, hot-dry, warm-humid, and temperate); and
5. to limit heat loss from the building envelope (excluding roof) in cold climatic zone[3].

Out of the above listed provisions, the building envelope solutions sets for Eco-Niwas Samhita 2018 helps in meeting two provisions of the code:

1. Maximum value of thermal transmittance of roof (U_{roof}) for all climate zones To limit heat gain/loss from the roof, a maximum value of thermal transmittance of roof (U_{roof}) for all climate zones is defined as 1.2 W/m^2.K.

   This document gives roof construction solutions to help meet the requirement of U_{roof} given in the code document.
2. Maximum value of residential envelope transmittance value (RETV) for building envelope (except roof) for four climatic zones (composite, hot-dry, warm-humid, and temperate)

   To limit heat gain from the building envelope (excluding roof) in four climatic zones (composite, hot-dry, warm-humid, and temperate), a maximum value of residential envelope transmittance value (RETV) for building envelope (except roof) is defined as 15 W/m^2. RETV depends on multiple parameters, which includes orientation, wall construction (U-value of wall), glazing properties (U-value and solar heat gain coefficient [SHGC]), WWR, and shading of windows.

   This document gives the solution for wall construction, window shading, and glazing options. A combination of these solutions will most likely help the user to make an informed choice on how to best meet the RETV requirement as per ENS Part 1 for a particular building.

USING THE DOCUMENT

This document contains details of external wall construction, roof construction, window shading, and glazing options to help meet the above two provisions. Each solution set gives a brief description of the construction assembly, its detailed drawings, steps of construction, technical specifications, and cost analysis as per market analysis carried for Rajasthan.

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1 A minimum value of openable window-to-floor area ratio (WFR_{op}) for each climate zone is defined. Hence, based on the climatic zone, minimum WFR_{op} can be taken from Table 1 of the code document. Multiplying this value with the carpet area, gives the value of minimum openable area for code compliance. If a project has lesser openable area, then it must be increased to meet the minimum requirement. An example of WFR_{op} calculation is given in code document.

2 A minimum visible light transmittance (VLT) for different range of window-to-wall ratio (WWR) is defined. An example is given in the code document for the calculation of WWR. Based on the WWR, the minimum visible light transmittance (VLT) value can be taken from Table 2 of the code document. Selection of glazing with a VLT value that meets this requirement ensures compliance to the code.

3 A maximum value of thermal transmittance for building envelope (except roof) ($U_{envelope,cold}$) is defined as 1.8 W/m^2.K. $U_{envelope,cold}$ depends on the U-value of wall, the U-value of window, and WWR. Wall construction and glazing selection with low U-value helps in meeting this requirement. An example is given in the code document for the calculation of $U_{envelope,\ cold}$.

EXTERNAL WALL SOLUTION SET

SOLUTION 1: 230-MM FLY ASH BRICK WITH WITH 50-MM XPS

BRIEF DESCRIPTION

This solution set comprises a 230-mm fly ash brick with XPS (extruded polystyrene) of 50-mm thickness and 70–100-mm cladding of user's choice on the outer face. The insulation material XPS may be fixed with fasteners holed on the wall or pasted with an adhesive and chicken wire mesh. It is necessary to cover all cracks or gaps in the walls, edges of doors, window frames, and shutters to limit the infiltration of heat into the building. This will make the insulation effective and will help decrease the heat gain from surroundings. The stone/brick cladding is also used in this assembly at the outer last layer. This wall is generally raised flushed to the outer surface of the slab/beam/column.

Figures A and **B** given below shows detailed drawings that depict the wall assembly in plan and section.

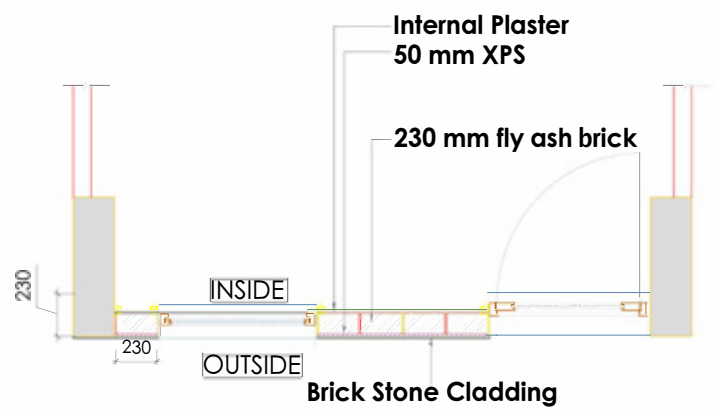


Figure A: Plan

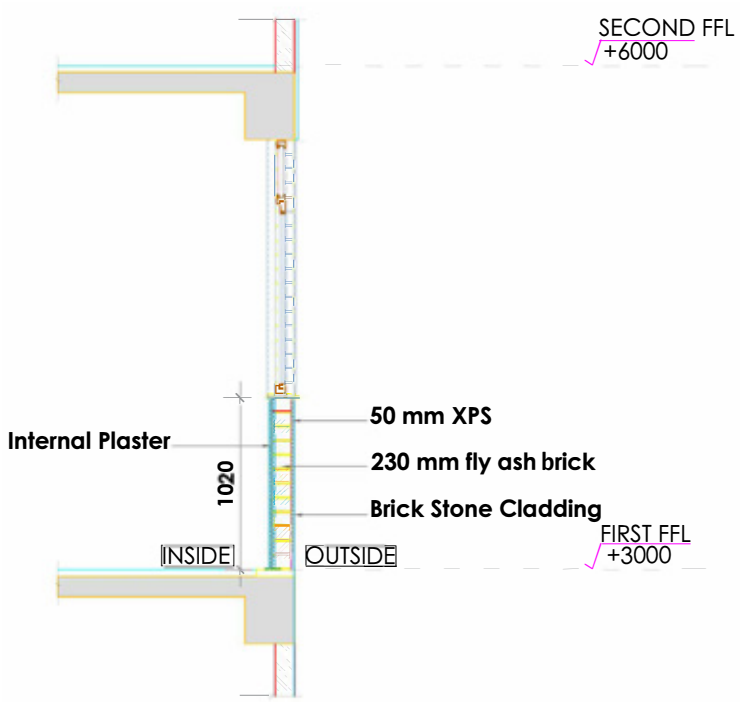


Figure B: Wall section with fly ash, XPS, and stone cladding

Figure 1: Fly ash bricks

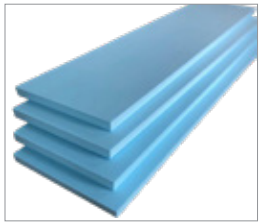


Figure 2: XPS sheets

Item Description for Bill of Quantities (BOQ)

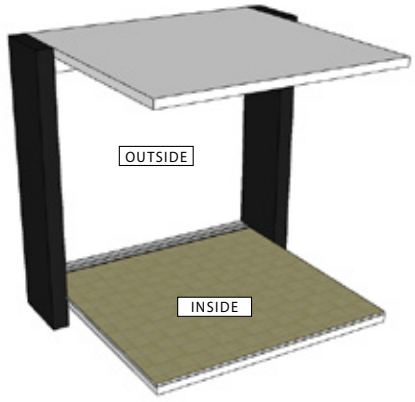
Fly ash brick masonry work using fly ash brick having minimum crushing strength not less than 75 kg/cm^2 after immersing the bricks for six hours in water before use in foundation and plinth, including splays cutting and circular molding, hoisting, watering, curing, etc. with 50-mm XPS and also stone/brick cladding.

0.44 W/m^2.K
U-value

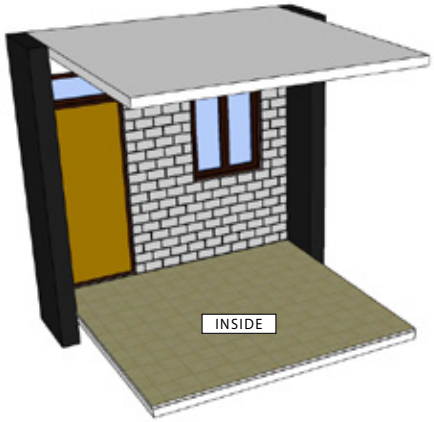
₹2250–2750#
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

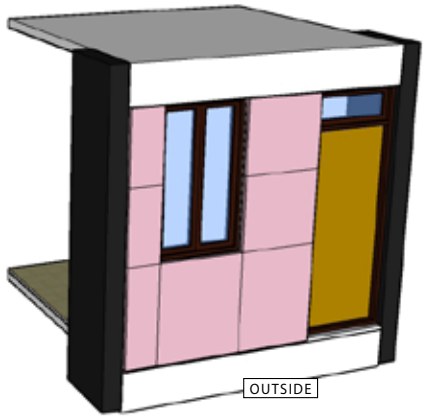
CONSTRUCTION STEPS



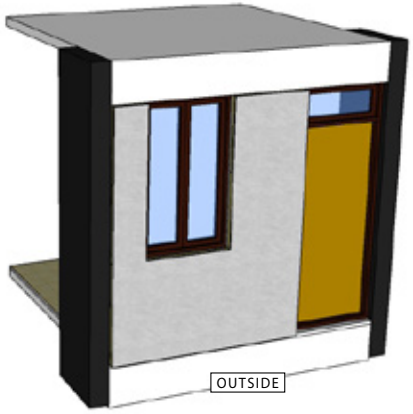
1 Lay the levelling course masonry on the floor with appropriate ratio of cement, sand, and water to begin brickwork from a flat surface.



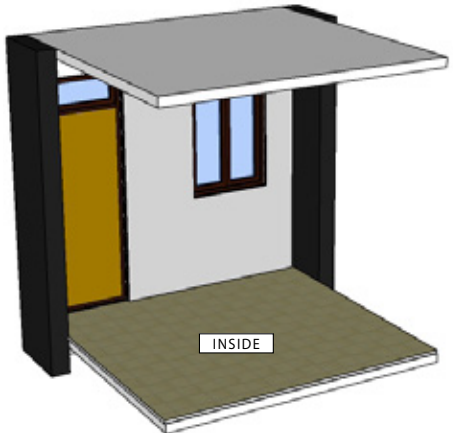
2 Start with laying 230-mm fly ash brick masonry one by one with cement mortar or levelling course between them up to the RCC level.



3 For wall insulation, install an XPS sheet with adhesives or bolts on the outer side of the wall.



4 Place any cladding over the XPS sheet using appropriate materials for pasting it.



5 Plaster the inner side of the wall.

SOLUTION 2: 200-MM-THICK AUTOCLAVED AERATED CONCRETE BLOCK

BRIEF DESCRIPTION

Autoclaved aerated concrete (AAC) block is a lightweight, load-bearing, high insulation block that comes in various thicknesses of 100 mm, 150 mm, and 200 mm. This wall assembly includes a 200-mm AAC block.

The outer face of the inner wall should be painted with a bitumastic paint layer to act as a vapour barrier in warm-humid climates. This paint also acts as an adhesive to bond the AAC block work to the inner wall. Figure A provides the top view of the assembly.

It is necessary to cover all cracks or gaps in the walls, edges of doors, window frames, and shutters to limit the infiltration so as to decrease the heat gain from surroundings. The internal and external surfaces of the 200-mm-thick AAC wall should be provided with a galvanized iron (GI) chicken wire mesh over the entire AAC block masonry, including the overlap at concrete-masonry junctions. This would help in avoiding shrinkage cracks in the future. The shrinkage cracks could be avoided by using this GI wire mesh.

Figures A and **B** show detailed drawings depicting the wall assembly in plan and section.

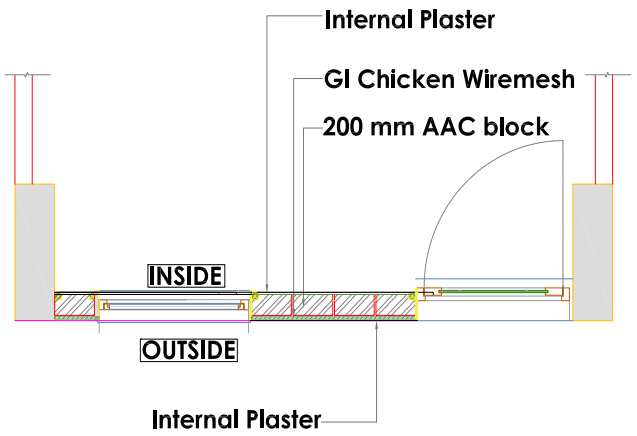


Figure A: Plan

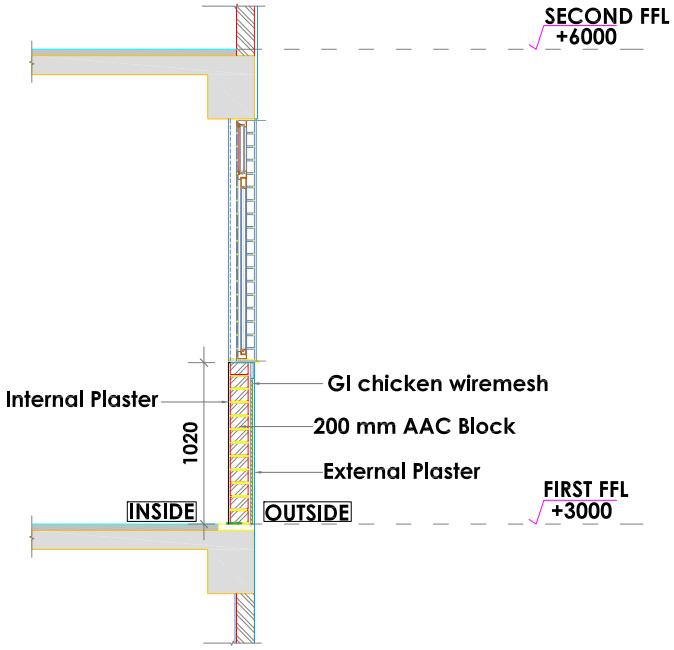


Figure B: Section

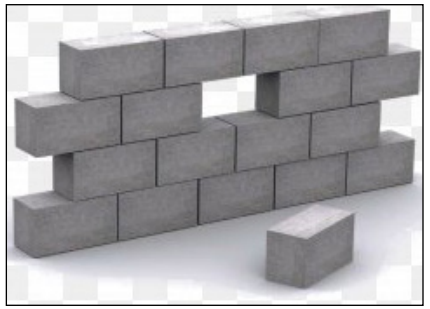


Figure 3: AAC Block

Item Description for BOQ

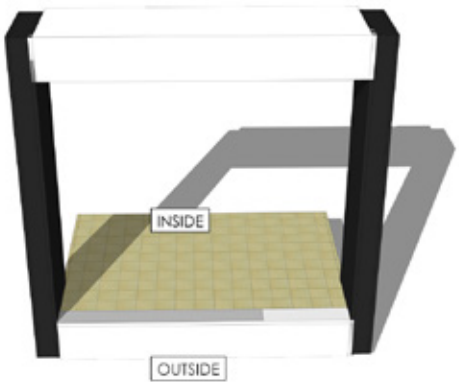
Providing and constructing AAC block masonry conforming to IS 2185 Part 3 with approved quality factory made Grade 1 AAC blocks of dry density of 551–650 kg/m^3, compressive strength of 4N/mm^2, water absorption less than 15%, thermal conductivity less than 0.24 W/m.K, interconnected by the zigzag GI wire of 3-mm diameter at alternate rows by welding in super structure above the plinth level up to the top-floor level in cement mortar 1:4 (1 cement : 4 coarse sand). The rate includes providing and placing in third course of masonry work.

0.77 W/m^2.K
U-value

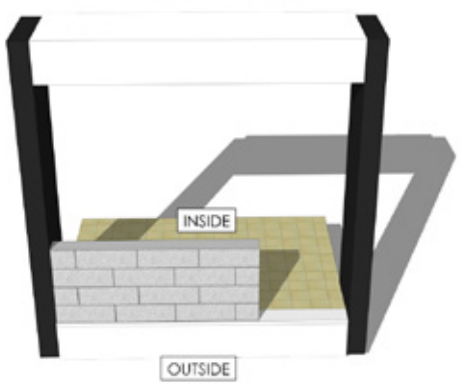
₹1700–2100#
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

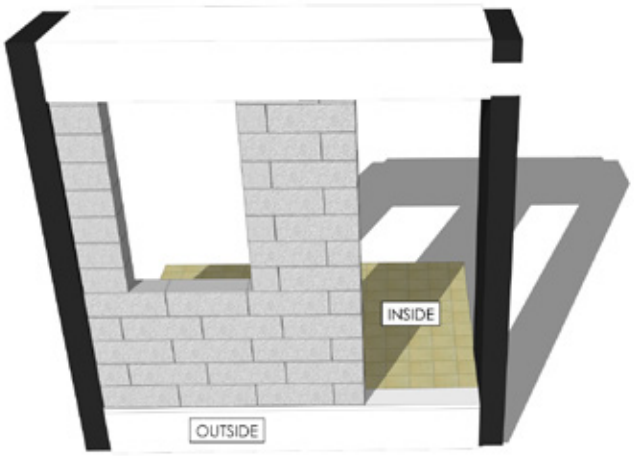
CONSTRUCTION STEPS



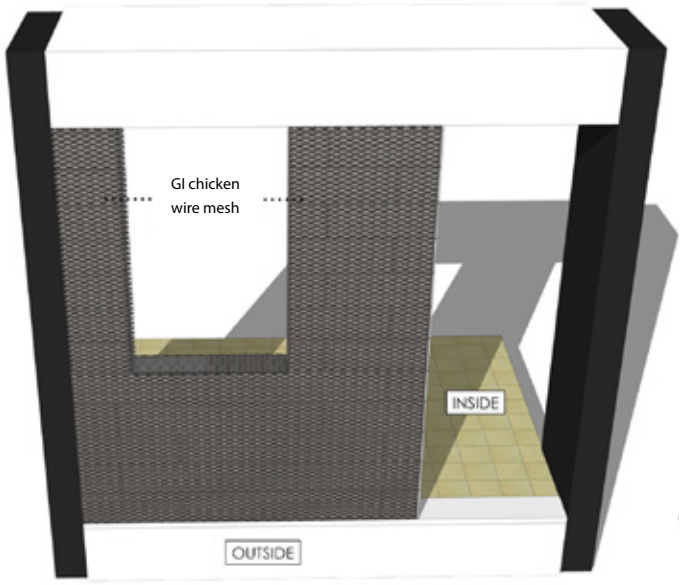
1 Lay the levelling course (above 400 mm) so as to begin brickwork from a flat surface.



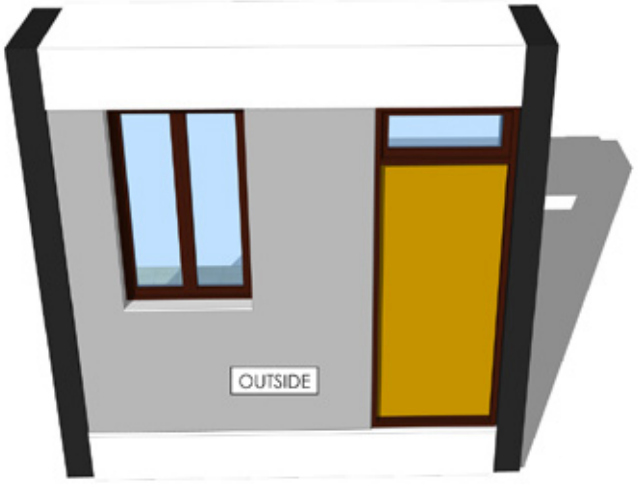
2 Lay AAC blocks of size 200 x 200 x 400 mm.



3 Raise the wall and provide openings for doors and windows.



4 Fix GI chicken wire mesh over the entire surface of blocks and structure overlap.



5 Plaster the wall and fix doors and windows.

SOLUTION 3: 200-MM AAC BLOCK WITH 50-MM AIR GAP AND 100-MM AAC BLOCK

BRIEF DESCRIPTION

The wall assembly comprises a 200-mm autoclaved aerated concrete (AAC) block, 50-mm air gap, and a 100-mm AAC block. An AAC block is a lightweight, load-bearing block with high insulation. It comes in various thicknesses – 100 mm, 150 mm, and 200 mm.

The outer face of the inner wall should be painted with bituminous paint layer to act as a vapour barrier in warm-humid climates. This paint acts as an adhesive also, which binds the AAC block work to the inner wall.

It is necessary to cover all cracks or gaps in the walls, edges of doors, window frames, and shutters to limit the infiltration so as to decrease the heat gain from surroundings. The internal and external surfaces of the 200-mm-thick AAC wall should be provided with a GI chicken wire mesh over the entire AAC block masonry, including the overlaps at concrete-masonry junctions. This would help in avoiding shrinkage cracks in the future. The shrinkage cracks could be avoided by using this GI wire mesh.

Figures A and **B** given below shows detailed drawings that depict the wall assembly in plan and section, respectively.

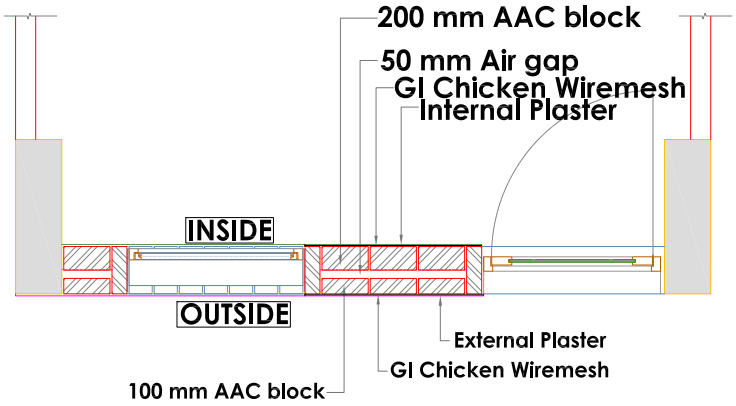


Figure A: Plan

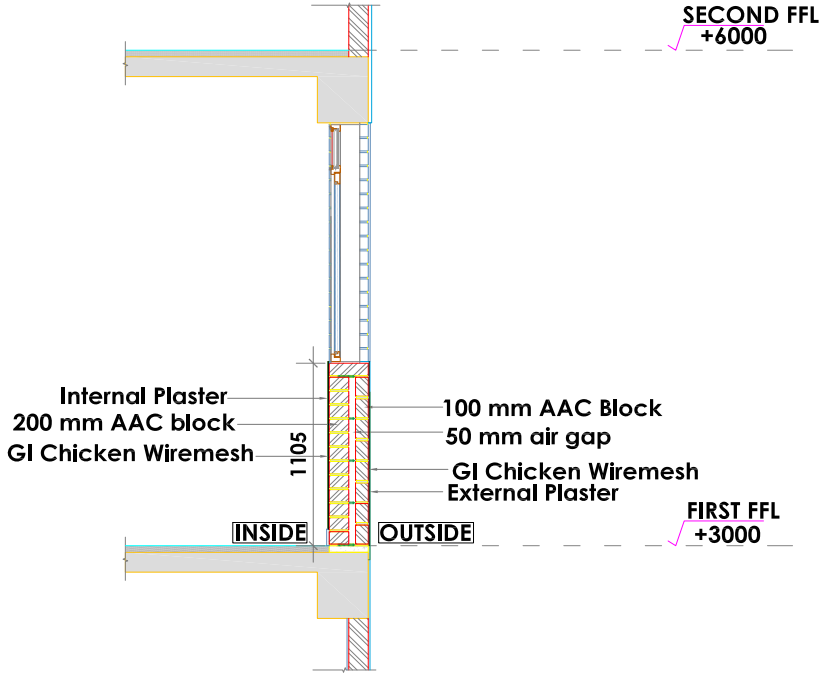


Figure B: Section

Item Description for BOQ

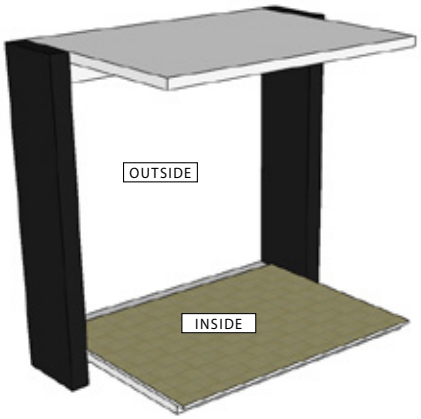
Providing and laying masonry assembly of 200-mm-thick AAC blocks, 50-mm air gap, and 100-mm AAC block with approved quality factory made Grade 1 AAC blocks of dry density of 551–650 kg/m^3, compressive strength of 4N/mm^2, water absorption less than 15%, thermal conductivity less than 0.24 W/m.K. This is to be interconnected by a zigzag GI wire mesh of 3-mm diameter at alternate rows by welding in the super structure above the plinth level up to the top-floor level in cement mortar 1:4 (1 cement : 4 coarse sand). The rate includes providing and placing in third course of masonry work.

0.5 W/m^2.K
U-value

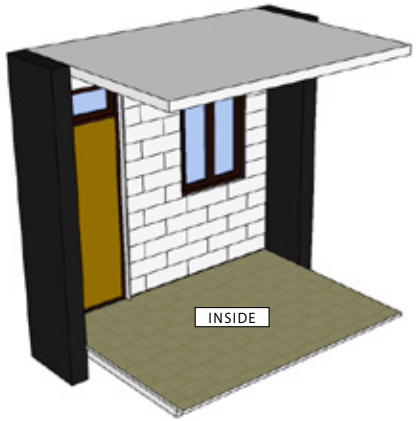
₹2300–2800$^{\#}$
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

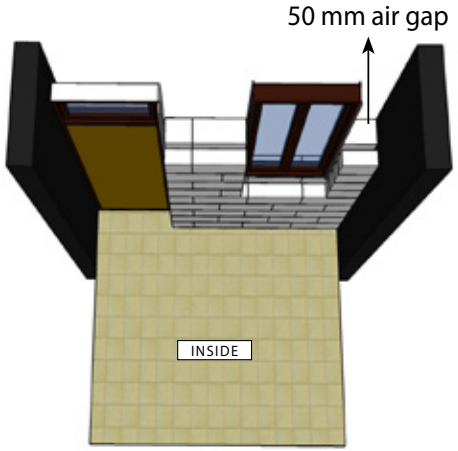
CONSTRUCTION STEPS



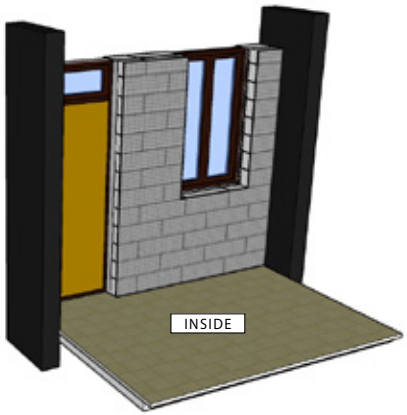
1 Lay the levelling course masonry on the floor with appropriate ratio of cement, sand, and water to begin masonry work from a flat surface.



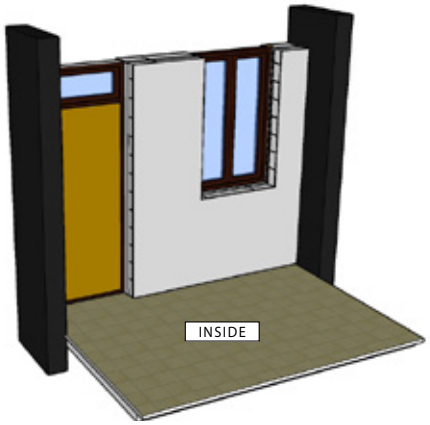
2 Lay 200-mm AAC block masonry one by one with cement mortar or levelling course between them up to the RCC level.



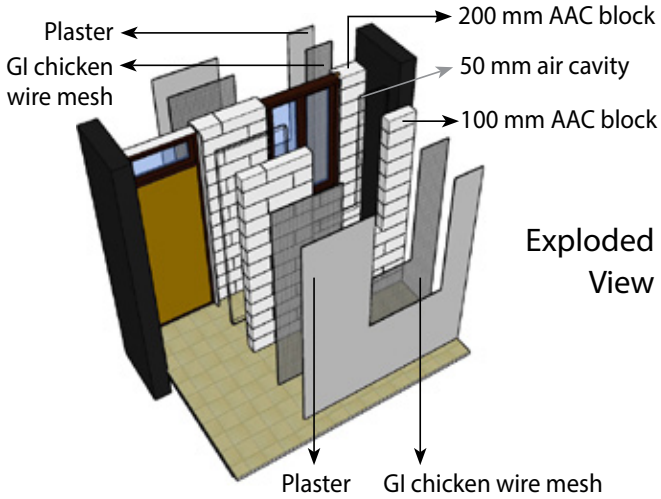
3 Place a 100-mm AAC block with a space of 50-mm air gap from the 200-mm AAC block.



4 Install a GI chicken wire mesh over the whole wall using bolts to prevent the plaster layer from drying out and cracking in both directions.



5 Plaster the inner side and the outer side of the wall.



Exploded View

SOLUTION 4: 115-MM THICK BRICK WALL WITH 100-MM THICK AAC BLOCK OUTSIDE

BRIEF DESCRIPTION

This wall assembly comprises a 100-mm-thick AAC block work on the outer wall and a 115-mm-thick burnt brick on the inner wall. The outer face of the inner wall should be painted with a bituminous paint layer to act as a vapour barrier in warm-humid climates. The total wall assembly will be 230-mm thick. The assembly can be raised a few courses at a time, the AAC wall being raised after painting the outer surface of the brick wall with bituminous paint. This paint acts as an adhesive also, which binds the AAC block work to the inner wall. **Figure A** provides the top view of the assembly.

The exposed area of RCC structure to the outside, which can be as much as 15%–20% of the envelope wall area, remains a thermal bridge between inside and outside. Now the wall starts from this projection. This protects the outer surfaces of the RCC structure from conductive heat gain. The details of the wall section are shown in **Figure B**.

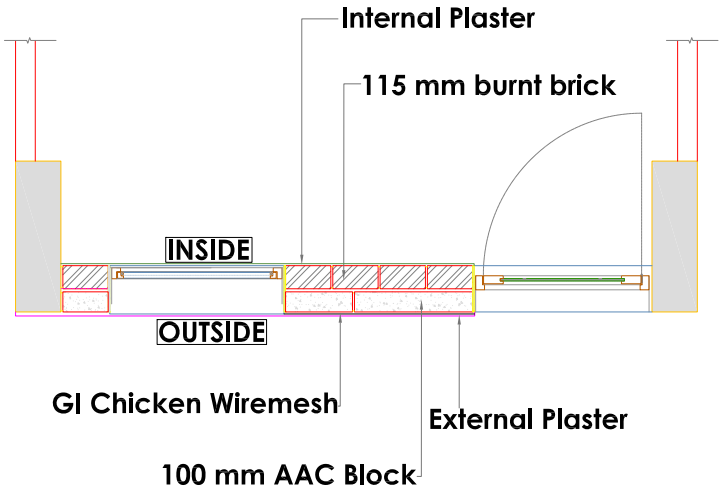


Figure A: Plan

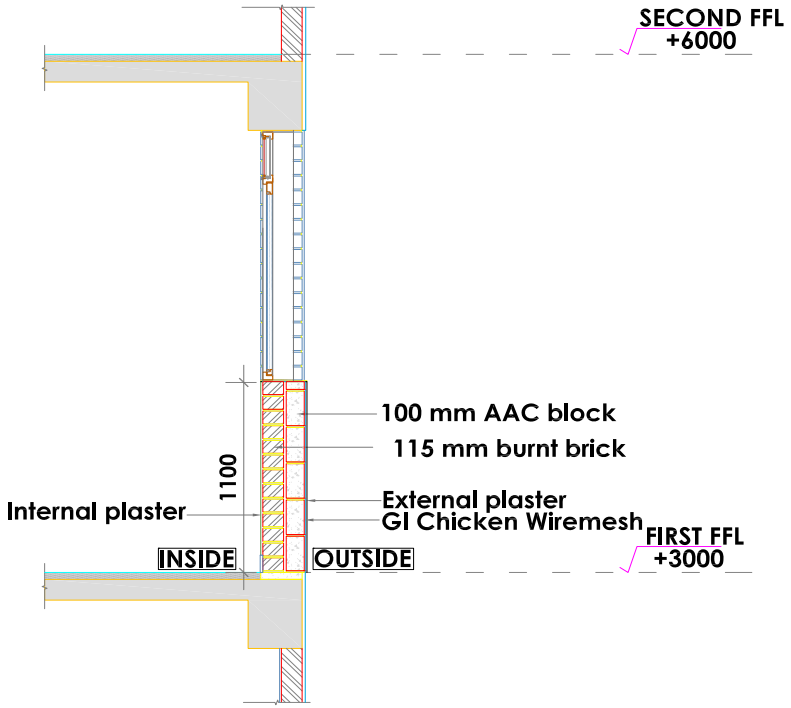


Figure B: Section of respective wall assembly

Item Description for BOQ

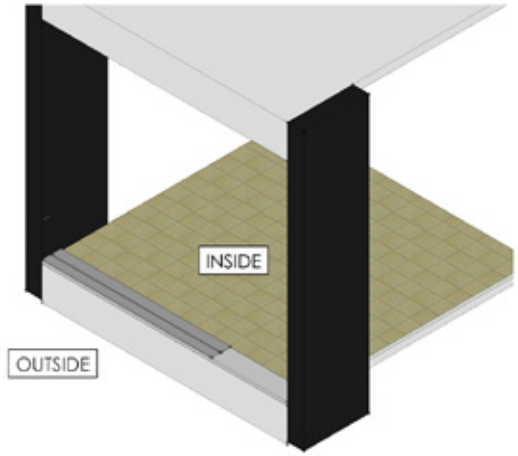
Providing and laying 100-mm-thick AAC wall on the outer face and 115-mm-thick brick wall on the inner face. The inner face of the 115-mm brick wall is painted with bituminous paint in warm-humid climate, which acts as a vapour barrier.

1.1 W/m^2.K
U-value

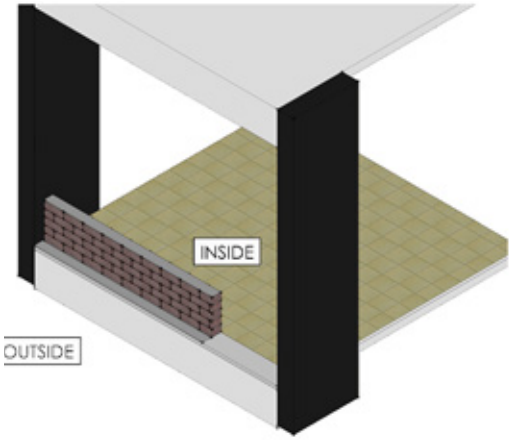
₹1900–2300#
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

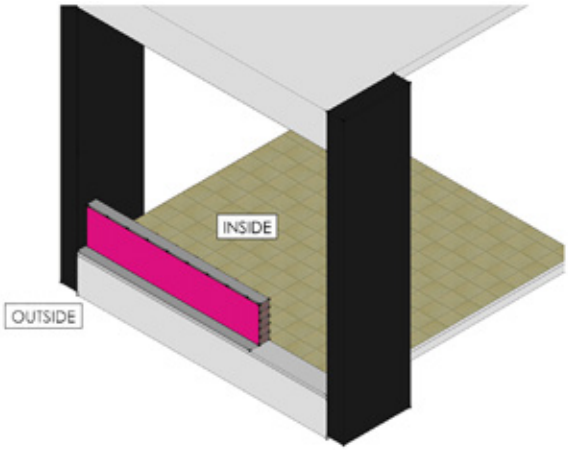
CONSTRUCTION STEPS



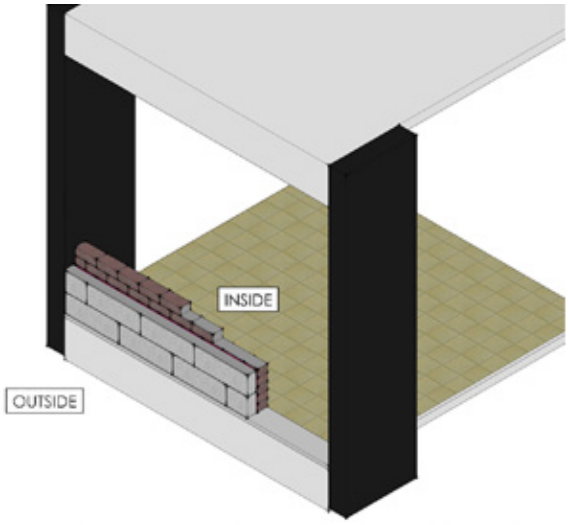
1 Lay the levelling course (about 400-mm) to begin brickwork fro a flat surface.



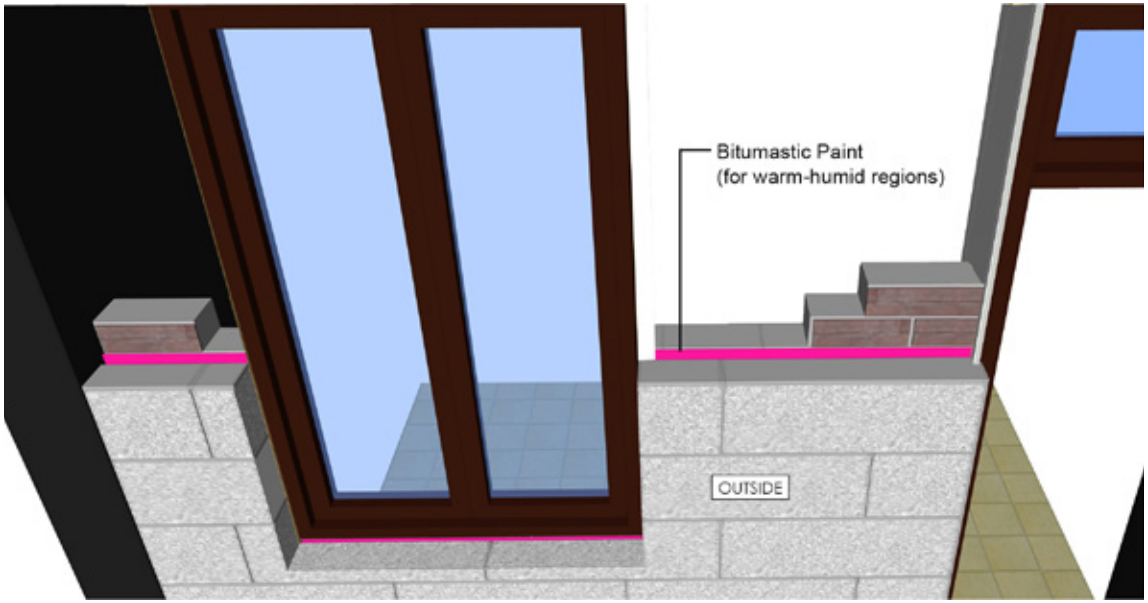
2 Raise the interior 115-mm-thick brickwall.



3 Apply Cementitious vapour barrier in warm-humid climate.



4 Raise the exterior 100-mm-thich AAC blockwork, after leaving a 15-mm gap.



5 The bitumastic paint (vapour barrier) here also acts as an adhesive that binds the outer AAC wall to the inner wall.

SOLUTION 5: 150-MM CLC BLOCK

BRIEF DESCRIPTION

A cellular lightweight concrete (CLC) block is an air-cured concrete block with fly ash as the major component and water. It is further mixed with stable foam in a concrete mixer under ambient conditions. This construction is suitable for low-rise load-bearing constructions. The wall assembly includes a 150-mm CLC block with 15-mm external and 12-mm internal plaster. It is three times less in weight than clay or fly ash blocks. A 100-mm-thick CLC wall will be equivalent to the dense concrete wall having more than 5 times thickness and almost 10 times in weight.

CLC offers high thermal insulation and weight reduction to the wall assembly. It is necessary to cover all cracks or gaps in the walls, edges of doors, window frames, and shutters to limit the infiltration to decrease the heat gain from surroundings. The shrinkage cracks could be avoided by using the GI wire mesh. By using a timber section, the end cavities of the doors and windows can be fixed properly without any gaps.

Figures A and **B** given below shows detailed drawings depicting the wall assembly in the plan and section, respectively.

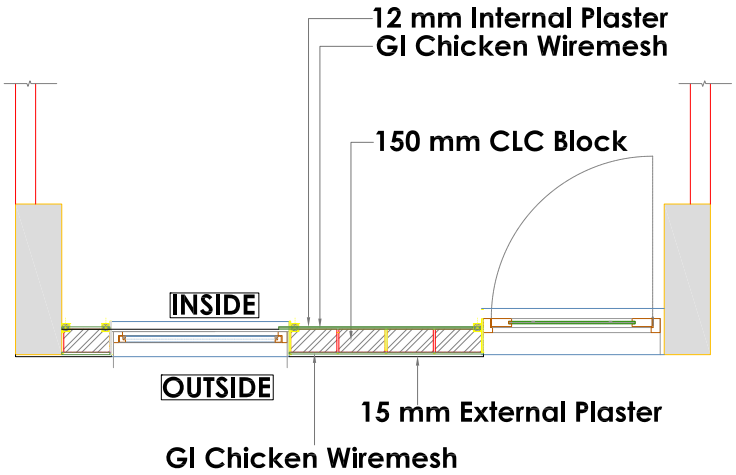


Figure A: Plan

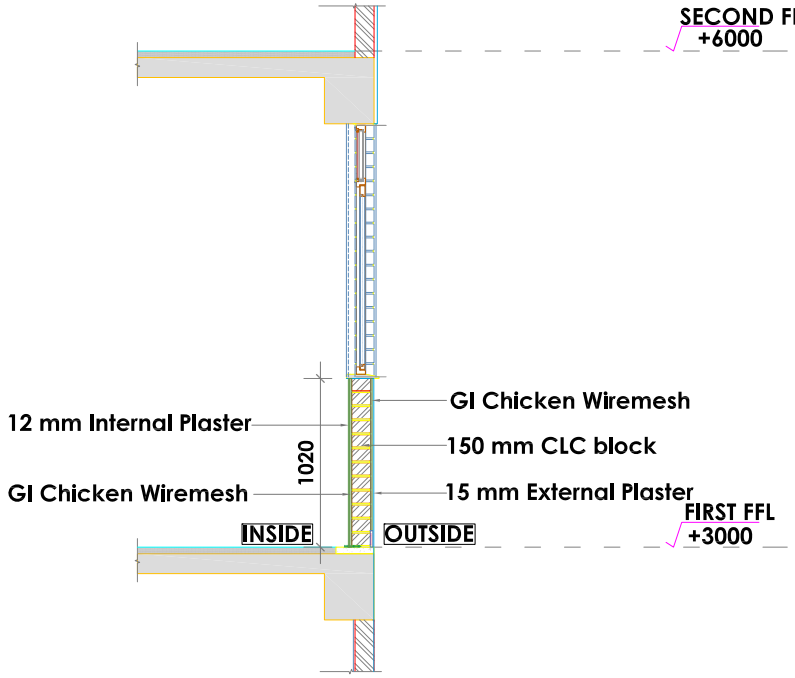


Figure B: Section

Item Description for BOQ

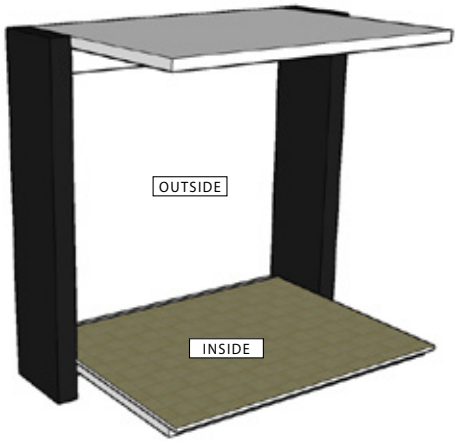
Providing 150-mm CLC block work having minimum crushing strength use in foundation and plinth, including splays cutting and circular molding, hoisting, watering, curing, etc. with 15-mm outside and 12-mm internal plaster and interconnected by the zigzag GI wire mesh of 3 mm diameter at alternate rows by welding. All materials and cost of all labour and T&P for the work in all respect as per the direction of the Engineer-in-Charge.

0.69 W/m^2.K
U-value

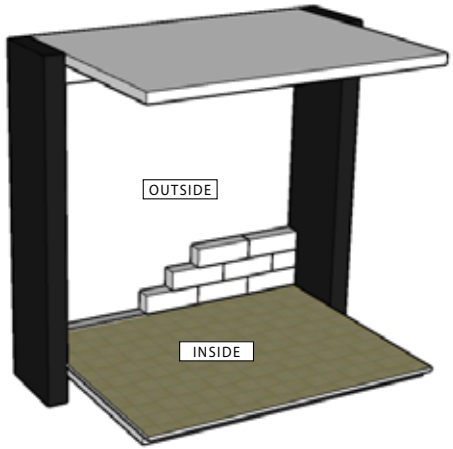
₹1100–1300$^{\#}$
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

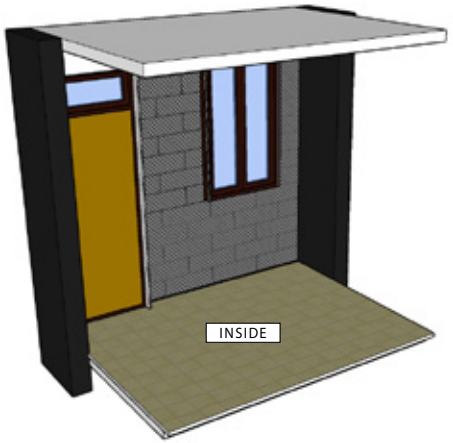
CONSTRUCTION STEPS



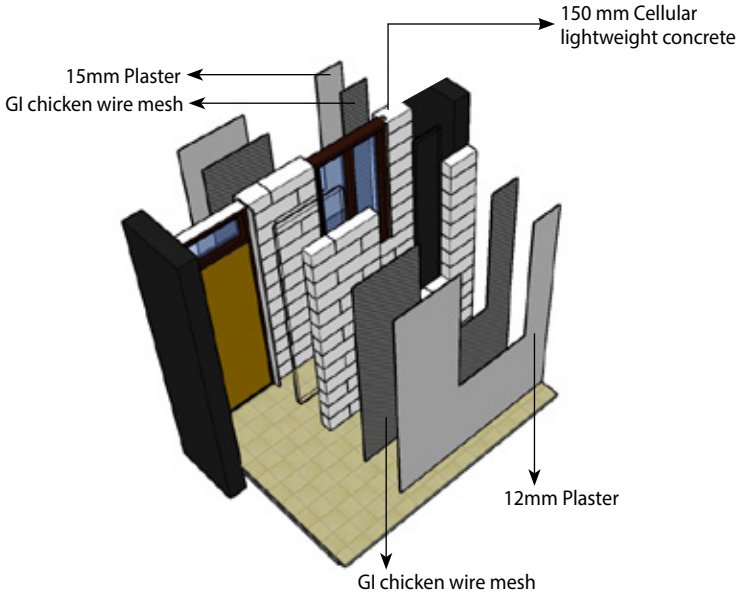
1 Lay the levelling course masonry on the floor with appropriate ratio of cement, sand, and water to begin the masonry work from a flat surface.



2 Lay 150-mm CLC block masonry one by one with cement mortar between the blocks up to the RCC level.



3 Install a GI chicken wire mesh over the whole wall using bolts to prevent the plaster layer from drying out and cracking and increase its strength.



4 Plaster the inner and the outer sides of the wall.

SOLUTION 6: 150-MM REINFORCED EPS CORE PANEL SYSTEM

BRIEF DESCRIPTION

The wall assembly includes a 150-mm expanded polystyrene (EPS) core panel system. This is a factory-produced panel system used for the construction of low-rise buildings like G + 3 and as filler walls in high-rise RCC and steel-frame buildings. In this, a core of undulated polystyrene is covered with interconnected zinc-coated welded wire mesh on both reinforcement and shotcrete concrete sides.

The EPS panels are usually manufactured with dimensions of 1200-mm width, 3000-mm length, and 80–230 mm thickness. The panels are finished on-site by pouring concrete (double panel, floors, and stairs) and spraying concrete to realize the vertical structure walls.

The EPS core panel system reduces the cost of construction, offers less construction time, and provides high level of thermal insulation.

Figures A and **B** provides detailed drawings that depict the wall assembly in the plan and section, respectively.

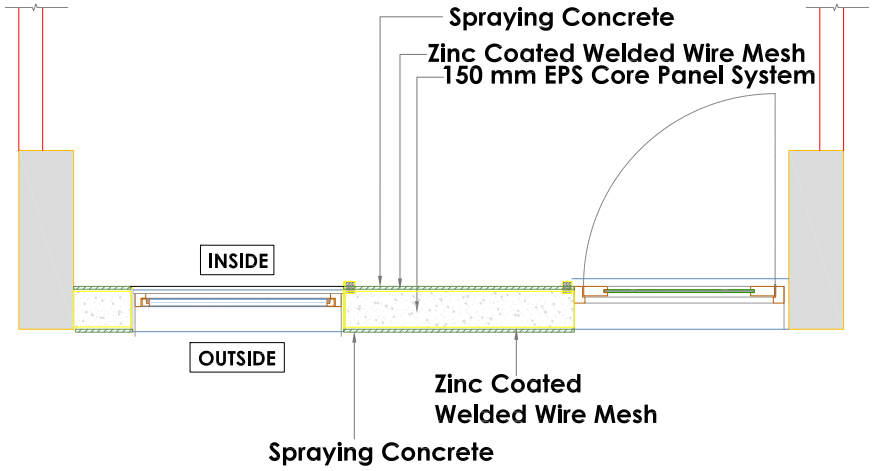


Figure A: Plan

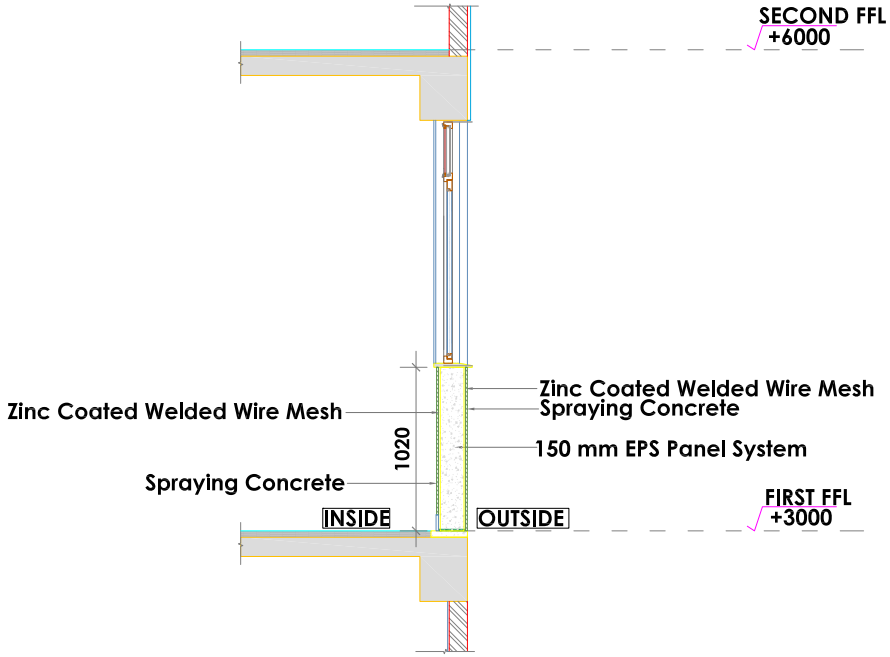


Figure B: Section

Item Description for BOQ

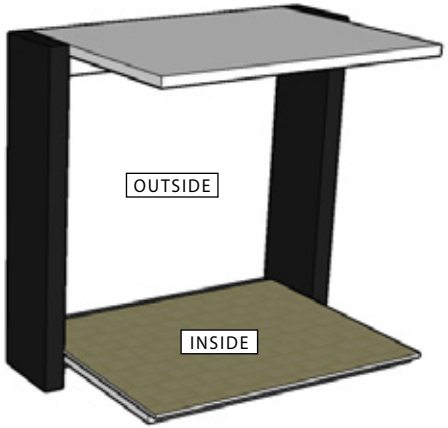
Providing factory made 150-mm EPS core wall /roof panel sandwiched between two engineered welded wire fabric mesh of 3-mm diameter, GI wire mesh with 150-mm pitch in both the directions, and interconnected by the zigzag GI wire mesh of 3-mm diameter at alternate rows by welding.

0.24 W/m^2.K
U-value

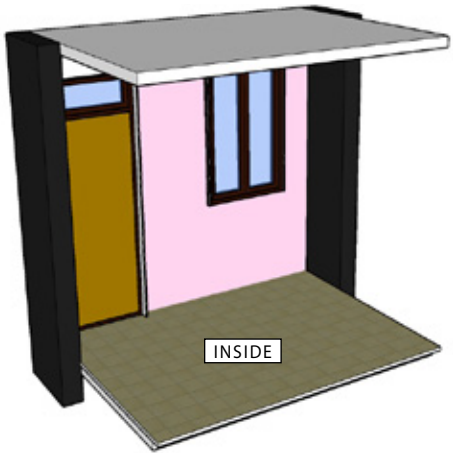
₹3700–4600#
Cost/m^3

 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

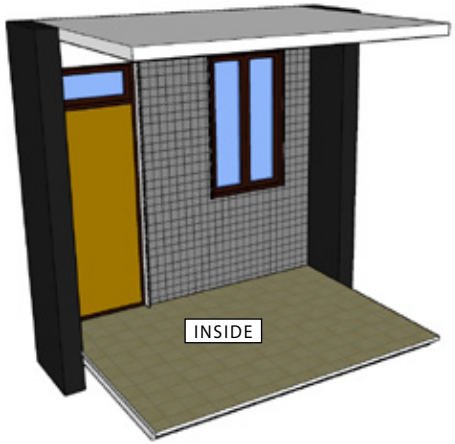
CONSTRUCTION STEPS



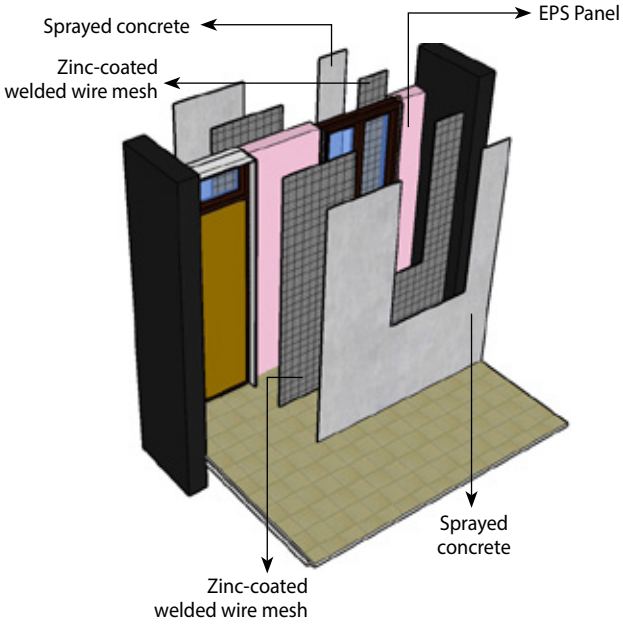
1 Lay the levelling course masonry on the floor with appropriate ratio of cement, sand, and water to begin the masonry work from a flat surface.



2 Place 150-mm-thick EPS panels up to the RCC level.



3 Install a zinc-coated welded wire mesh over the whole wall using bolts to prevent the panels from cracking on both sides on both sides.



4 Pour concrete by spraying over the whole wire mesh on both sides.

ROOF SOLUTION SET

SOLUTION 1: 150-MM RCC WITH 50-MM XPS AND 50-MM SAND SCREED

BRIEF DESCRIPTION

This roof solution set consists of a 150-mm-thick RCC layer, 50-mm XPS, and 50-mm sand screed to reduce the conductive heat loads from the roof. First the roof surface is flattened with screed to achieve a smooth finish. Then a waterproofing membrane is applied over the entire surface. The insulation (50-mm XPS) will be fixed with grouting fasteners on the roof or with an adhesive and chicken wire mesh layer.

The insulation board has an interlocking groove edge to hold on to each other. The insulation material should cover the entire roof surface and must be tight fitting on the roof. This is essential for the insulation to be effective.

As the waterproofing layer is below the insulation layer, the insulation material should be of a closed cell structure, which does not absorb water. Fibrous insulation material cannot be used due to the high absorption tendency of water.

Then, to achieve the slope on the terracing, lay sand screed (minimum 50 mm) over the insulation that slopes towards the Khurra of the rainwater pipes. This concrete layer is further finished with a China mosaic/light colour tile finish. The light colour helps reflect the incident solar radiation.

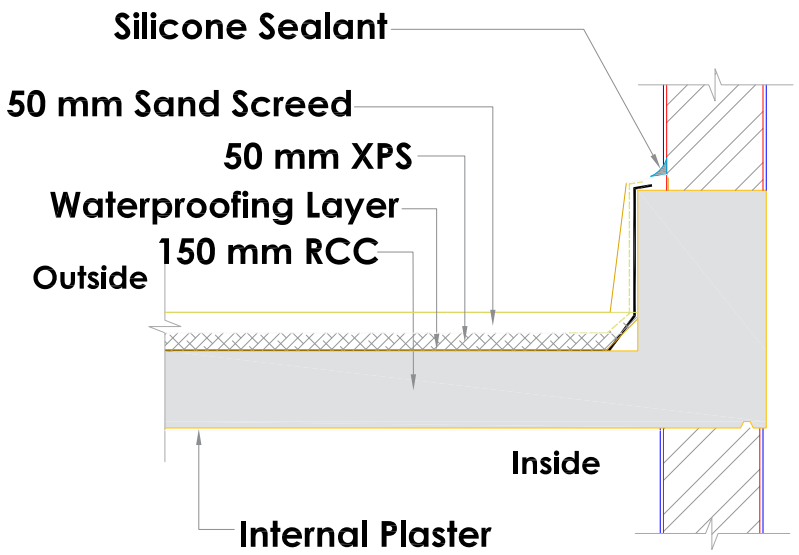


Figure A: Section of the roof assembly

Figure 4: XPS sheets

Item Description for BOQ

Providing and fixing 50-mm-thick extruded polystyrene (EXP) rigid insulation board of required size complying with ISO 4898:2008 and ASTM C 578-08b - Type VI, having thermal conductivity of 0.0289 W/m.K as per ASTM C 578 (measured as per IS 3346), compressive strength of > 350 kPa listed as per ASTM D 1621, density of 34–36 kg/m^3 as per ASTM D 1622, water absorptions < 1% by volume as per ASTM D 2842, fixed with suitable water-based adhesive and fastener, complete in all respect as per the direction of the Engineer-in-Charge.

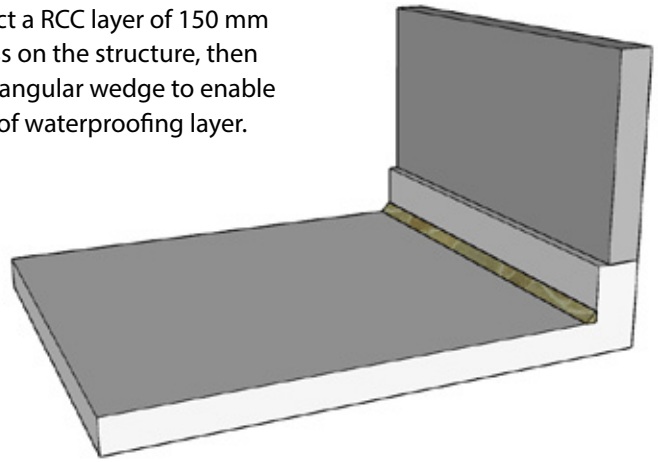
0.52–0.56 W/m^2.K
U-value

₹4000–4850#
Cost/m^3

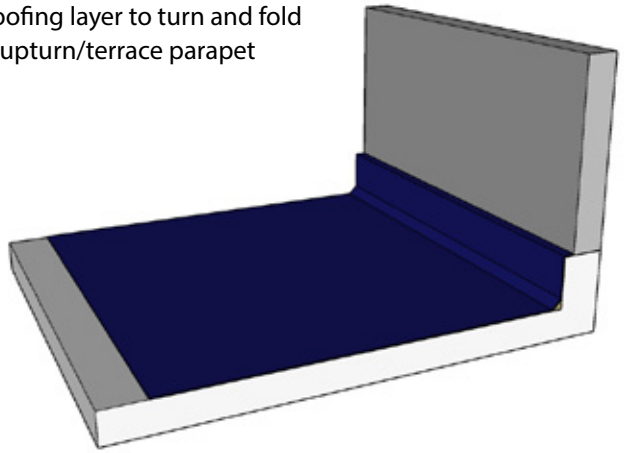
 # The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

CONSTRUCTION STEPS

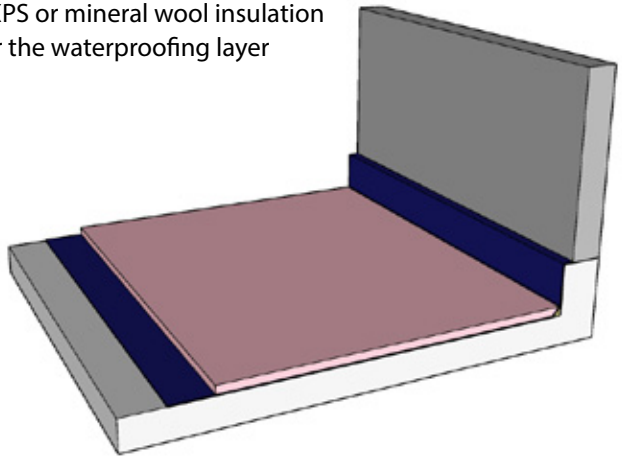
1 Construct a RCC layer of 150 mm thickness on the structure, then add a triangular wedge to enable turning of waterproofing layer.



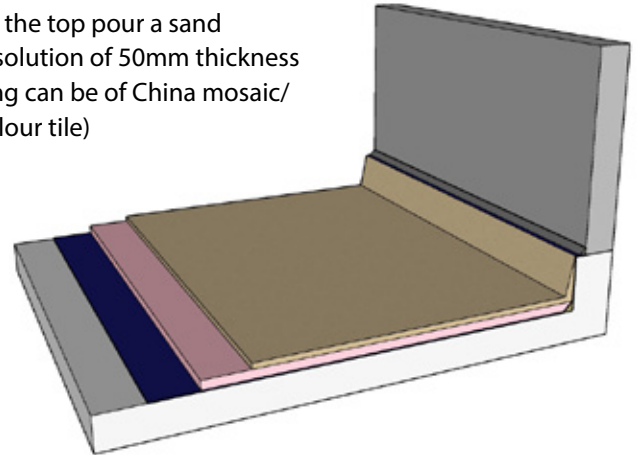
2 Waterproofing layer to turn and fold over the upturn/terrace parapet base.



3 Install an XPS or mineral wool insulation board over the waterproofing layer



4 To level the top pour a sand screed solution of 50mm thickness (finishing can be of China mosaic/ light colour tile)



SOLUTION 2: 150-MM RCC WITH 50-MM FOAM CONCRETE AND 50-MM SAND SCREED

BRIEF DESCRIPTION

This roof assembly comprises a 50-mm-thick foam concrete insulation to reduce the conductive heat loads from the roof. First, the RCC roof surface is covered in foam concrete of 50-mm thickness. Then a waterproofing membrane is applied over the entire surface.

The foam concrete is made of a combination of stable foam, water, sand, and cement and has a porous nature. Therefore, it is required to be below the brickbat coba. Instead of waterproofing layer, brickbat coba can also be used for waterproofing on the roof. Finally, the sand screed solution is applied on brickbat coba, which is a mixture of sand, cement, and water at an appropriate ratio.

This concrete layer can be further finished with a China mosaic/light colour tile finish. The light colour helps reflect the incident solar radiation. The detailed drawing depicts the roof assembly in sectional view (**Figure A**).

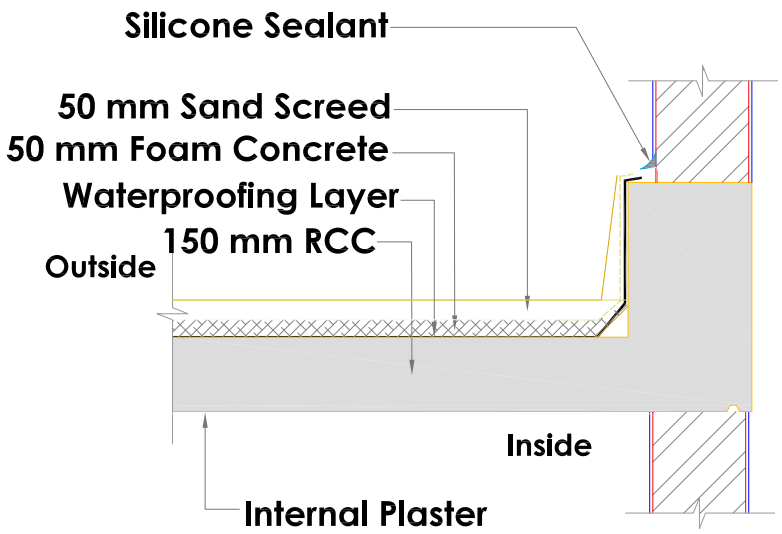


Figure A: Section of the roof assembly

Figure 5: Foam concrete installation on roof

Item Description for BOQ

Pouring 100-mm-thick foam concrete insulation over the waterproofing surface having a thermal conductivity of 0.07 W/m.K, density of 320 kg/m^3. The compressive strength is 0.5–1.0 N/mm^2 (Source: British Concrete Association). The laying is done through foam concrete pouring machine. Complete in all respect as per the direction of the Engineer-in-Charge.

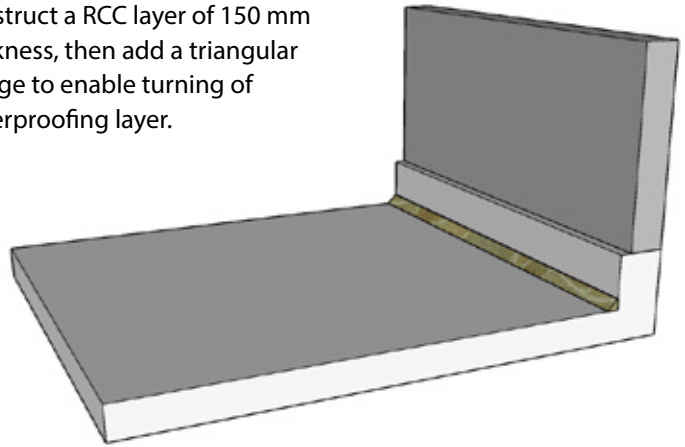
0.9–1.0 W/m^2.K
U-value

₹5000–5500#
Cost/m^3

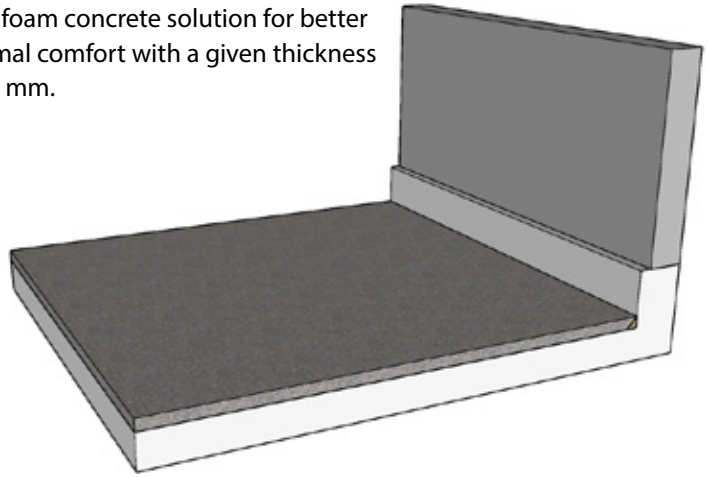
The cost calculations are done based on the information collected from a) market survey done in Rajasthan under Indo-Swiss Building Energy Efficiency Project (BEEP) in 2020, and b) BSR (Basic Schedule of Rate) 2019 for Rajasthan. It is recommended to calculate the cost based on updated local rates for material, labour, taxes, etc.

CONSTRUCTION STEPS

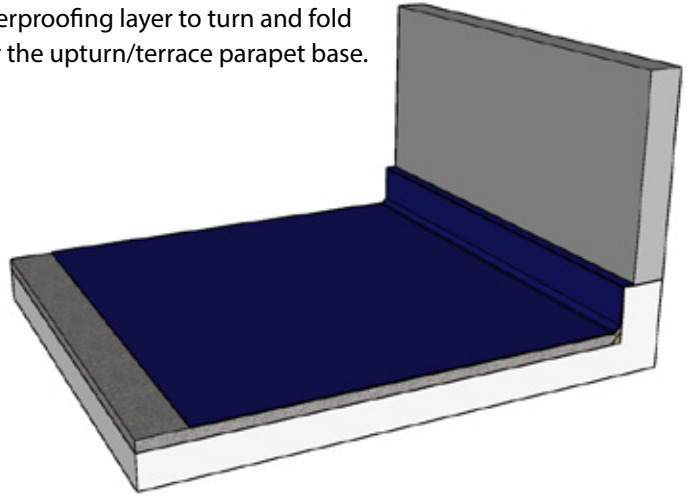
1 Construct a RCC layer of 150 mm thickness, then add a triangular wedge to enable turning of waterproofing layer.



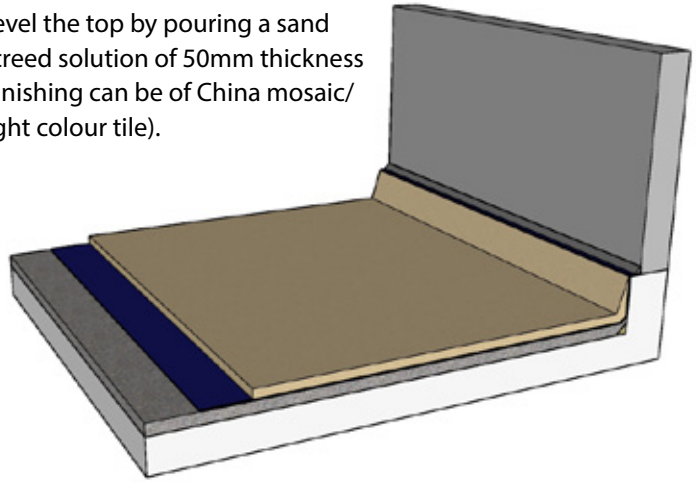
2 Pour foam concrete solution for better thermal comfort with a given thickness of 50 mm.



3 Waterproofing layer to turn and fold over the upturn/terrace parapet base.



4 Level the top by pouring a sand screed solution of 50mm thickness (finishing can be of China mosaic/ light colour tile).



WINDOWS SOLUTION SET

BRIEF DESCRIPTION

Glazing (non-opaque surfaces) used in window openings allows solar radiation to penetrate inside the space, which results in considerable amount of heat gain. Non-opaque surfaces in windows can trap the heat inside the space due to which the inside temperatures can sometimes be greater than the ambient temperatures.

Therefore, along with designing optimum openings where glazing area should be reduced as per requirement and providing adequate shading devices, it is also recommended to use a better performing glazing. These glazing options have a low U-value and low SHGC, which reduces the heat gain through window conduction and window transmittance, respectively.

Within the building envelope solution sets, the commonly used glazing options for residential buildings are provided.

Technical specifications and terms commonly used for glass

U-value:

Thermal transmittance (U value) is the heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side. Unit of U-value is $W/m^2.K$. The U-value for a wall/roof/glazing indicates its ability to transfer heat through conduction.

Solar factor/Solar heat gain coefficient:

Solar heat gain coefficient or SHGC is the fraction of incident solar radiation admitted through non-opaque components, both directly transmitted, and absorbed and subsequently released inward through conduction, convection, and radiation (**Figure A**).

Visible light transmission:

Visible light transmission (VLT) is the ratio of the total transmitted light to the total incident light. It is a measure of the transmitted light in the visible portion of the spectrum through a material.

Source: Eco-Niwas Samhita 2018

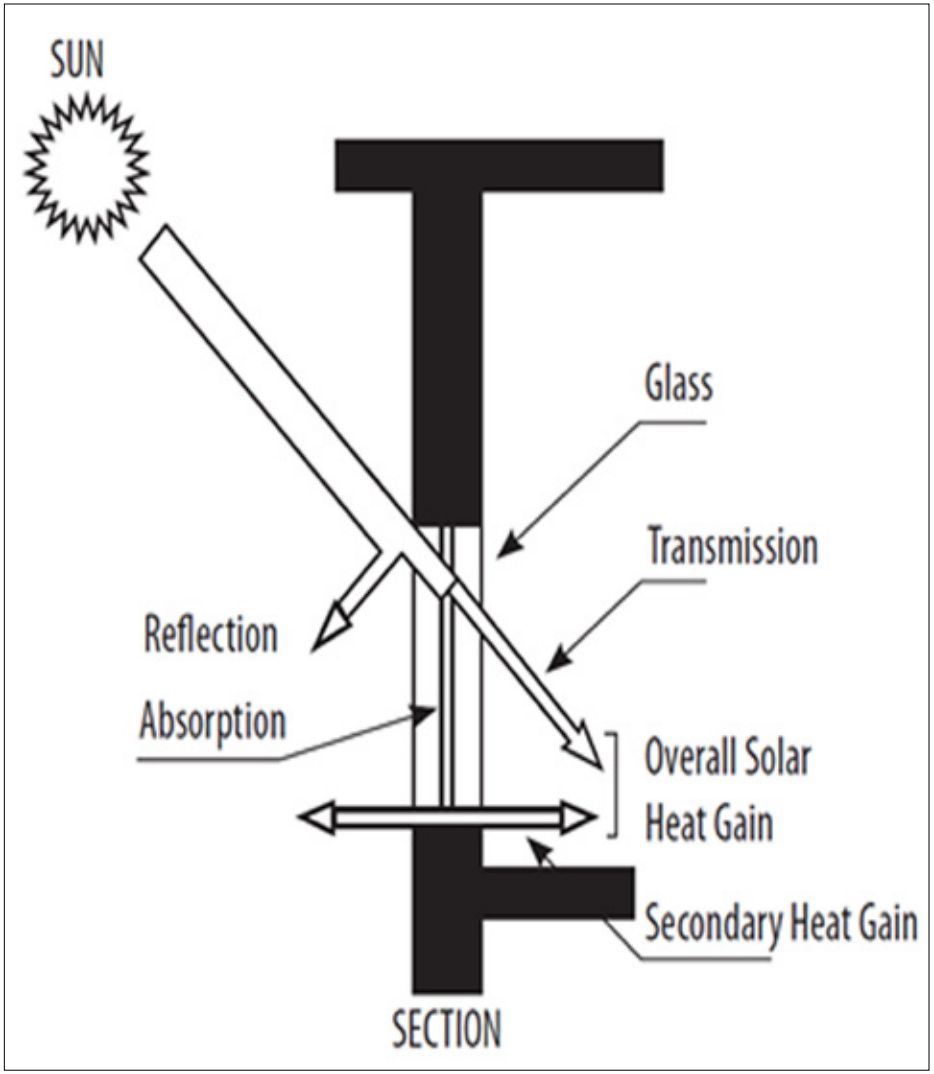


Figure A: SHGC of a glass

ALUMINIUM + SGU GLASS SLIDING WINDOW WITH REFLECTIVE GLASS

The window solution consists of an aluminium sliding frame with SGU (Single Glazed Unit) with an SHGC (solar heat gain coefficient) of 0.53 or lower and VLT of 0.51 or higher. The window pane could alternatively be casement type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.53 or lower	0.51 or higher	6 mm	5.6 $W/m^2.K$	₹4300–5300/m^2

uPVC + SGU GLASS SLIDING WINDOW WITH REFLECTIVE GLASS

The window consists of an uPVC (unplasticized polyvinyl chloride) sliding frame with SGU with an SHGC of 0.53 or lower and VLT 0.51 or higher. The window pane could alternatively be casement type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.53 or lower	0.51 or higher	6 mm	5.6 $W/m^2.K$	₹5400–6500 /m^2

ALUMINIUM + SGU GLASS CASEMENT WINDOW WITH REFLECTIVE GLASS

The window solution consists of an aluminum casement frame with SGU with an SHGC of 0.53 or lower and VLT 0.51 or higher. The window pane could alternatively be sliding-type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.53 or lower	0.51 or higher	6 mm	5.6 $W/m^2.K$	₹4400–5400/m^2

uPVC + SGU GLASS CASEMENT WINDOW WITH REFLECTIVE GLASS

The window solution consists of a uPVC casement frame with SGU with an SHGC of 0.53 or lower and VLT 0.51 or higher. The window pane could alternatively be sliding-type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.53 or lower	0.51 or higher	6 mm	5.6 $W/m^2.K$	₹5900–7200/m^2

ALUMINIUM + DGU 6-MM CLEAR + 12-MM AIR GAP + 6-MM CLEAR CASEMENT WINDOW

The window solution consists of an aluminium casement frame with DGU (Double Glazed Unit) with an SHGC of 0.69 or lower and VLT 0.78 or higher. The window pane could alternatively be sliding-type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.69 or lower	0.78 or higher	6 mm	2.8 W/m^2k	₹5800– 7100/m^2

uPVC + DGU 6-MM CLEAR + 12-MM AIR GAP + 6-MM CLEAR CASEMENT WINDOW

The window solution consists of a UPVC casement frame with DGU with an SHGC of 0.69 or lower and VLT 0.78 or higher. The window pane could alternatively be sliding-type also. Typically, the glass is of 6-mm thickness with a solar heat control film layer.

SHGC	VLT	THICKNESS	U-VALUE	COST
0.69 or lower	0.78 or higher	6 mm	2.8 W/m^2k	₹6300–7700/m^2

EXTERNAL SHADING SOLUTIONS

External shading can minimize the solar heat gain for non-opaque surfaces/windows. Shading can be either horizontal, vertical, or inclined. Horizontal shade is ideally installed just above the windows at the lintel level, and vertical fins could be placed on either side depending on the direction of the sun. The projection should be lightweight, non-porous material like cement board.

An external shading device over windows opening is designed to cut off direct solar radiation when it is undesirable. The shading options listed below consist of fixed shading options (overhang, side-fins, and jaalis) as well as external movable shading systems (shutters, awnings, and foldable screens).

GREEN NET

The green net is a temporary shading device, which generally comes in green colour with very fine mesh. The net is made out of nylon material. This net controls the heat reduction and sunlight in occupied spaces. Higher degree of UV stabilization helps the shade net last longer. Other properties like high chemical and wind resistant, light weight and easy to handle make it a good option for shading.

₹40–60 Cost/m^2

ROLL-UP BLINDS

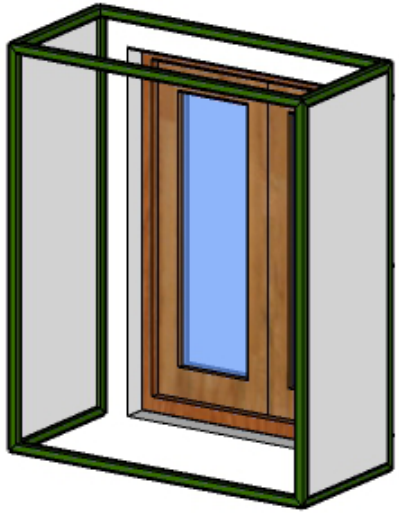
In roll-up blinds, the top rail acts like a frame to anchor the screen. The bottom rail is used to roll the screen up or down. Commonly, bamboo chick blinds are used and they are fabricated from raw bamboo weaved with strings. Typically, these designs make for a traditional look along with heat reduction and light control properties. The solar control features such as blocking the heat from outward help in heat reduction in the space.

₹55–60 Cost/m^2

FINS

The shading elements restrict direct solar radiation from the sides when the sun is at a lower altitude. This is often designated as an affixed element. It could be made from cement boards, perforated metal sheets, punched louvers GI panel, concrete/GRC jali, boards, bamboo, welded MS flats, or a weather-resistant fabric.

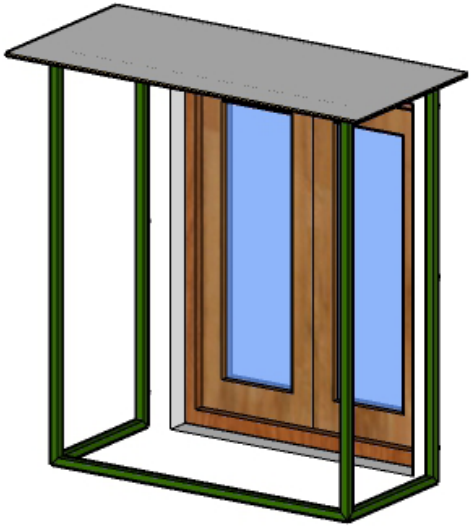
₹200-250 Cost/m^2



OVERHANG

This horizontal projection above windows shields it from direct solar radiation when the sun is at a high altitude, and protects it from rain. Materials such as cement board, precast concrete panels, and stone are usually used for overhangs. Many times, they are cast *in situ* also. The used depth is between 300 and 450 mm and they are placed above the lintel. Sometimes, if larger overhangs are to be provided, they are placed at the bottom of the beam (instead of just above lintel), to hold them in place due to the weight of the beam.

₹200-250 Cost/m^2



WOODEN SHUTTERS

Wooden shutters are usually installed into the window frame and consist of louvers, made of either wood or a poly resin that can either be stationary or tilt. They do not move up and down like blinds but in certain applications can fold across the window.

***₹10,000–15,000** Cost/m^2

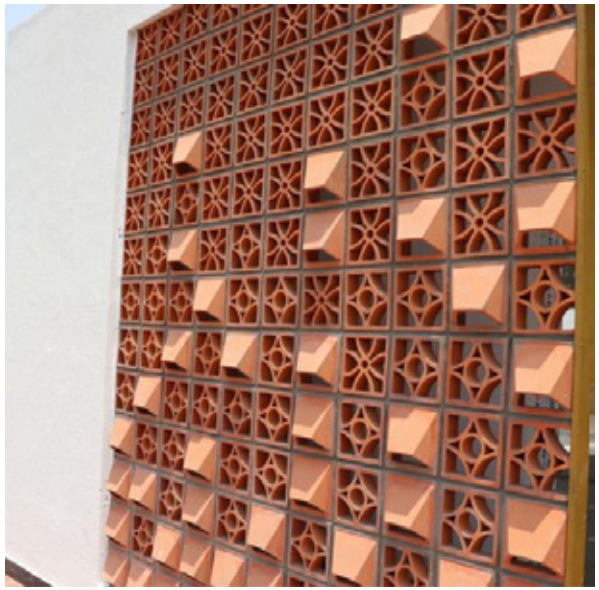
* Motorization cost will be additional, i.e., ₹18 000–30 000 per window opening (depending on the weight and size of the window)

CLAY TILE JALI

Clay jali products have already gained international fame and recognition. It is used where ventilation is necessary, but formwork is not essential. It is used for fences composed of walls and gardens.

Clay jali designs help lower the temperature by compressing the air through the holes. In addition, when the air passes through these openings, its speed increases giving a deep diffusion.

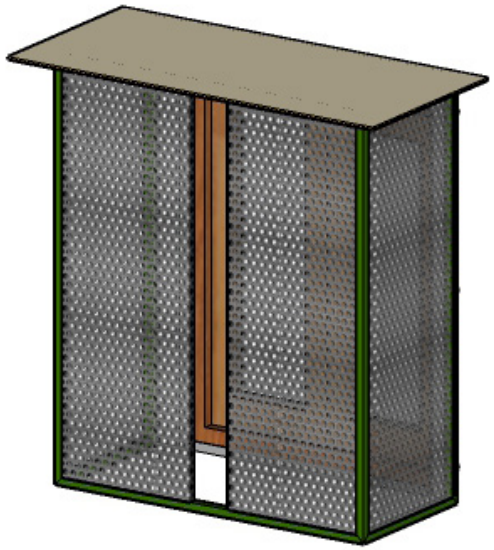
₹500–3000 Cost/m^2



METAL JALI

The Jali lattice work is usually made from mild steel, aluminium, stainless steel, brass, copper, and titanium material and carved in customized sizes and patterns as per the clients' specifications. These help in providing shade along with facilitating natural ventilation.

₹1100–1300 Cost/m^2



SHUTTER WITH LOUVERS

Louvers are one of the most effective ways to reduce air-conditioning loads, while offering designers the opportunity for distinctive architectural impact. Radiation from the sun is transmitted, absorbed, and reflected by the louvers. As a result, solar heat gain is prevented from passing into the building. If an operable system is chosen, the adjustable louvers will track the position of the ssun. This will help not only in increasing the effectiveness of the shading system but also in reducing the glare. On overcast days, the operable louvers can be opened to maximize the natural daylight into the building.

₹6300–7700 Cost/m^2

FOLDABLE ARM AWNINGS

The awning designs are made up of aluminium extrusion rods that interlock with brackets, which, in turn, spreads the cantilevered force imposed by the awning into the structure it is fitted to. Hand-cranked awnings and motorized awnings are now common. In this, a simple rod is employed to open and close the awning.*

The crank is hooked to the roller and rotated clockwise; this motion releases the tension arms to stretch out and open. When the roller is rotated in anti-clockwise direction, the awning retracts. There are two hooks in the awning:

1. For opening and closing the awning.

2. For adjusting the pitch of the awning.

In motorized awnings, the motor is inside the roller tube that the fabric rolls around and therefore is not visible. The material can sustain wind and rain. The material of the fabric can be all-weather synthetic-based or natural like cotton-based.

₹2000–5000 Cost/m^2

** External Movable Shading Systems (EMsys) Manual, 2021, https://www.beeindia.gov.in/sites/default/files/EMSYS%20Manual_Web.pdf*

QUARTER-ROUND AWNINGS

Quarter-round awnings give three-sided protection from the sun and rain. They are available mainly in two shapes: spherical and rectangular. Quarter-round Foldable (spherical) Awning has the shape of a quarter sphere, and hence all the dimensions (height, projection length, and radius) are equal. (Also known as Bull Nose Awning.) The rectangular awning has multiple panels that are attached radially to the corner, which forms the sub-structural space frame. These panels are installed with solar fabric. The awning is pulled together and stretched on a rope and pulley system.*

₹2000–5000 Cost/m^2

** External Movable Shading Systems (EMsys) Manual, 2021, https://www.beeindia.gov.in/sites/default/files/EMSYS%20Manual_Web.pdf*

IMAGE REFERENCES

Figure 1: Fly ash bricks
https://www.indiamart.com/proddetail/fly-ash-bricks-15181791433.html

Figure 2 and 4: XPS sheets
https://xps.en.alibaba.com/product/60823594638-200262802/100mm_10cm_Thickness_XPS_Extruded_Polystyrene_Foam_Board_Blocks_with_High_Quality.html

Figure 3: AAC Block
http://www.ecogreenproducts.in/aboutus.php

Figure 5: Foam concrete installation on roof
https://theconstructor.org/concrete/quality-applications-foam-concrete-construction/16010/

Green Net: https://www.amazon.in/Khandaka-Multi-Purpose-NET-15-Stitched/

Clay Tile Jali: https://www.indiamart.com/proddetail/clay-jali-blocks-21168063055.html

About Building Envelope Solution Sets

This ready-reckoner set of solutions is made to facilitate the implementation of the *Eco-Niwas Samhita 2018, Part I: Building Envelope* in the state of Rajasthan. It contains details of external wall construction, roof construction, and window shading to help meet the Residential Envelope Transmittance Value (RETV) and roof U-value requirements for composite, and hot-dry climatic zones of Rajasthan. Each solution set gives a brief description of the construction assembly, its detailed drawings, steps of construction, technical specifications, and cost analysis as per Basic Schedule of Rates (BSR) 2019 for Rajasthan.

About Bureau of Energy Efficiency

Bureau of Energy Efficiency (BEE) is a statutory body under the Ministry of Power, Government of India. It assists in developing policies and strategies with the primary objective of reducing the energy intensity of the Indian economy. BEE coordinates with designated consumers, designated agencies, and other organizations to identify and utilise the existing resources and infrastructure in performing the functions assigned to it under the Energy Conservation Act.

About Rajasthan Renewable Energy Corporation Limited

The Rajasthan Renewable Energy Corporation Limited (RRECL) is the state designated agency of the Bureau of Energy Efficiency in the state of Rajasthan and is working for enforcement of provisions of Energy Conservation Act 2001 in the State. RRECL has been actively involved in taking effective measures for energy conservation, with a track record of special achievements and innovations made in the energy sector.

About the Indo-Swiss Building Energy Efficiency Project

The Indo-Swiss Building Energy Efficiency Project (BEEP) is a bilateral cooperation project between the Ministry of Power, Government of India, and the Federal Department of Foreign Affairs of the Swiss Confederation. The overall goal of the project is to reduce energy consumption in new commercial, public, and residential buildings in India through energy-efficient and thermally comfortable design. The project has four key components: building design, building technologies, building policy, and outreach.

For further information

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The Ministry of Power, Government of India, has launched *Eco-Niwas Samhita (ENS) 2018 or Energy Conservation Building Code for Residential Buildings (ECBC-R), Part I: Building Envelope* on 14 December 2018. The code defines provision for building envelope to reduce heat gain/loss and improve natural ventilation and daylighting potential.

To facilitate the implementation of ENS 2018 in the state of Rajasthan and to cater to region-specific requirements, state-specific building envelope solution sets have been developed titled, 'Towards Eco-Niwas Samhita Implementation in Rajasthan: Building Envelope Solution Sets'. *The Rajasthan Building Envelope Solution Sets (2022)* have been prepared after delving into practical and directly implementable solutions drawn through a market survey conducted in the state. The primary objective of this publication is to help building designers in the adoption of ENS 2018 at the state level.

This publication serves as a supplementing document that will help achieve the Residential Envelope Transmittance Value (RETV) and roof provisions for building envelope as per ENS 2018 in the state of Rajasthan. It is prepared in such a manner that it will help users to make an informed choice on how best to meet building envelope-related code provisions in Rajasthan.

FOR FURTHER INFORMATION

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