MAINSTREAMING ENERGY EFFICIENT BUILDING DESIGN PRACTICES IN STATE PUBLIC WORKS DEPARTMENTS

Vernica Prakash Kapoor, Indo-Swiss Building Energy Efficiency Project (BEEP), India Sameer Maithel, BEEP, India
Pierre Jaboyedoff, BEEP, Switzerland Saswati Chetia, BEEP, India Prashant Bhanware, BEEP, India

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ABSTRACT

State Public Works Departments (PWDs) and other similar government departments responsible for the construction of public buildings in the states have an important role in making the public building energy efficient and thermally comfortable as well as in the implementation of the Energy Conservation Building Code (ECBC). Well-designed, energy-efficient public buildings have a large demonstration effect. Many countries have adopted the strategy of show-casing energy-efficient design, technologies and design practices by first adopting them for the public buildings. The Schedule of Rates (SoR) and other technical documents of PWDs are also referred by the private sector builders, thus influencing the construction industry practices of the private sector as well.

The paper is based on the experience of working with the PWDs and other state departments responsible for construction of public buildings in three states: Karnataka, Rajasthan and Andhra Pradesh. A three-step approach was adopted for engaging with the state agencies: a) conducting seminars to create awareness, b) providing technical support for integration of energy efficiency strategies in the design of specific public building projects, and c) development of state-specific guidelines for design of energy efficient and thermally comfortable public buildings. The paper presents the approach and learnings. It also present ideas for better and effective engagement with the state PWDs to help in mainstreaming energy efficient building design practices in state PWDs.

INTRODUCTION

Energy Conservation Building Code (ECBC) was formulated by the Bureau of Energy Efficiency (BEE) in 2007 (BEE 2007). ECBC sets minimum energy standards for commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above. The implementation of the code depends primarily on the state governments (state governments notifying the code for the state or amending the existing General Development Control Rules) and the urban local bodies (for amending building regulations to incorporate ECBC provisions) (Rawal et al. 2012).

The construction of public buildings in states is generally carried out by the state government departments e.g. Public Works Department (PWD), other state government departments or public-sector enterprises. These agencies are an important player in the implementation of ECBC, as:

a) They are responsible for the construction of state governments buildings and hence are responsible for the adoption of the code in buildings constructed by them.
b) They are the technical experts at the state level and hence play an important role in the framing the adapted version of the state building energy conservation code.
c) Faster adoption of the ECBC by state government construction departments and agencies and inclusion of materials and technologies used for the construction of energy efficient buildings in the Schedule of Rates (SoRs), provide a fillip to the market for these materials and technologies as these are referred widely by the private sector construction companies
d) As the public buildings are visited by public, well designed energy efficient and thermally comfortable (EETC) public buildings can have large demonstration effect and can help in creating awareness about building energy efficiency.

Many countries have adopted the strategy of show-casing energy-efficient design, technologies and design practices by first adopting them for the public buildings (Liu et al. 2010)

As a part of a bi-lateral development cooperation project aimed at supporting BEE programme on building energy efficiency, activities were undertaken to provide technical assistance to state government construction departments and agencies. The programme is ongoing and activities have been taken up in three states – Karnataka, Rajasthan and Andhra Pradesh. It is to be noted that all the three states were the first few states in the country to notify ECBC. However, the process of on-ground implementation of ECBC remains slow in all the three states.

METHODOLOGY

The methodology for engaging with the state level construction departments and agencies consisted of three measures:

1. Awareness Creation: Organisation of awareness seminar(s) in each state to create awareness about energy efficient building design. These seminars were organised in association with the state departments and were mainly attended by the officials (architects and engineers) of state PWDs. In some cases representatives from the local chapters of associations of building professionals and builders also attended the seminars. The awareness seminar content covered the following topics a) Introduction to EETC buildings b) Integrated design process c) Passive design strategies d) Energy efficient space cooling technologies and systems e) Case studies of EETC public buildings. In some cases, field visits to EETC buildings were also organised as a part of the awareness creation exercise.

2. Technical Assistance: Having set up the links in the state and after gaining basic understanding of the process and institutions involved in the design and construction of public buildings, the next step was to provide technical assistance to integrate EETC strategies in the design of specific public buildings being designed and constructed by these state agencies. This assistance was offered in two ways:

   a) Technical assistance for revision of template design for small public buildings which are replicated in various districts: The assistance consisted of i) analysis of the proposed design of the building by carrying out sun-path analysis, day light analysis and in some cases building energy simulations ii) providing design inputs during a 1-day workshop and submitting a detailed technical report subsequently. No follow up technical support during construction was provided.

   b) Technical assistance by conducting design charrettes and during construction for large public buildings: The assistance consisted of i) detailed analysis of the proposed design of the building by carrying out building energy, day light, computational fluid dynamics (CFD) simulations ii) providing design inputs for integrating EETC strategies by conducting a 3-4 day long design workshop iii) providing need based technical support during construction to assist in the implementation of the EETC design.

3. Design Guidelines: The third step was the development of guidelines for design of EETC public buildings for the state. The guideline document in the form of a manual is to be used by the designers of public buildings.

ANALYSIS & RESULTS

AWARENESS CREATION

Following are the learnings gained while conducting awareness seminars

a) Focussed presentations on integrated design process, design strategies and case studies were appreciated by the participants. However, participants wanted more information on application and cost, which were sometime lacking in the seminar presentations. The site visits to EETC buildings after the seminar proved effective. As many of the participating officials were field personnel, they preferred field visits and discussing details of implementation (e.g. application of insulation materials, selection and installation of external movable shading systems, etc) during site visits.

b) Though majority of the participants understood presentations made in English, they were more fluent and comfortable speaking in their mother tongue. Having one project team member fluent in the local language helped in facilitating interactions during the seminars.

c) The seminar organisation required pre-seminar preparatory meetings with government departments. These interactions were helpful in gaining familiarity and understanding roles of various departments and their expectations. This helped in making the seminar content more relevant to the state. It was observed that most of the state agencies have only basic information available on their websites, hence these interactions were also useful in gathering information regarding organisation structure, projects, etc.

TECHNICAL ASSISTANCE

Revision of Template Designs of Smaller Buildings

The PWDs have standard design templates for district level buildings, such as, district offices, district courts, hostels, etc. The typical process adopted for the design of such building involves making a master template, which is a detailed architectural design for the particular building type. The client (concerned government department) sanctions the number of buildings to be constructed in selected districts in a fixed budget. The construction process starts as and when the land is acquired. The site conditions may differ in all districts however, usually the building design remains the same. These buildings being small in size and budget, are generally mixed mode buildings in which only a few rooms are air-conditioned**.**

Technical support was provided for four buildings. Key information of these buildings and the EETC measures are provided in Table 1.

The results of the analysis of these buildings and EETC strategies identified are summarised below

a. Reducing heat gains from the building envelope: The heat gains from the building envelope primarily consists of heat conduction through roof, wall and glazing and directly transmitted solar gains. Reduction in heat gains was achieved through: i) proper orientation of the building to minimise heat gains, though in some cases, the site conditions restricted a change in the orientation; ii) In all the cases, roof was un-insulated concrete slab and addition of insulation was recommended in the revised template design; iii) In all the cases, the wall construction was of standard brick masonry, wall insulation was recommended in all the cases to restrict the heat gains. The Window to Wall Ratio (WWR) was in a reasonable range of 15-25% for all the buildings and the windows had provision for fixed shades. In the district courts at Banswara and Bengakuru and the District office at Bijapur, external movable shading was recommended for windows on the eastern and western facades

b. Improving daylighting: All the buildings being primarily day-use buildings offered scope for improving daylighting. Daylight simulations for typical spaces were carried out. In all the cases, the building floor plate was not very deep (< 20 m), which provided favourable conditions for good daylighting. Daylight improvement was achieved through reorganising of rooms in the floor plans and adjustment in room layouts to ensure better daylight availability on workstations. In some of the cases such as the District Office at Bijapur and the District Court at Banswara, redesign of the window (adding fixed pane at the top of the window) was recommended for improved daylight.

c. Natural Ventilation: All the buildings are mixed mode buildings, with large part of the building without air-conditioning. The potential of natural ventilation was investigated and changes in the design of the windows were suggested to improve natural ventilation. The window design changes also incorporated appropriate safety features so that the windows can be kept open for night ventilation.

The exercise to provide technical support for the revision of template design show the potential that exist for improving energy efficiency and thermal comfort in public buildings. However, the impacts of this exercise are still not fully visible and realised. One of the key learning was that inclusion of new materials (e.g. hollow burnt clay blocks or building insulation), building systems (e.g. window shutters, external movable shading systems) or new technologies (e.g. two stages evaporative cooling) in the PWD SOR is a must for these solutions getting implemented. Through the initiative of the ECBC cell and PWD, SOR revision has taken place in Karnataka, which is a welcome development.

On the other hand, delay in construction, e.g. the District Court building at Banswara, for which technical assistance was provided in 2014, has put a question mark on the implementation of the revised template design for this building. Retirement and transfers of key officials involved in the template revision process has resulted in temporary break in communication and has impacted the implementation process.

Technical assistance by conducting design charrettes for large public buildings

Detailed technical assistance was provided for the design of head office of the Rajasthan Forest Department, Jaipur having a built-up area of around 10,000 m^2. At the time when technical support was provided, the orientation and building massing was already finalized, hence the focus was more on building envelope and the space cooling system. Being the office of the forest department, the client wanted a sustainable building design.

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During the design workshop, the main emphasis was on reducing heat gains, improving day lighting, energy efficient lighting and cooling systems and integration of renewable energy. Following energy efficiency measures were agreed upon and were implemented:

- Roof insulation: Roof was insulated with 40 mm polyurethane foam (PUF) resulting a U-value of 0.6 W/m^2.K. Also, light coloured terrazzo tiles at top was incorporated to have high reflectivity.
- Wall insulation: External wall constructed as cavity wall filled with insulation. A 50 mm extruded polystyrene (XPS) insulation was used, resulting a U-value of 0.5 W/m^2.K (without taking account thermal bridging).
- Efficient glazing: Double glazed unit (6-12-6 mm) with U-value: 1.8 W/m^2.K, SHGC: 0.24 & VLT: 36% was used to reduce heat gains and get enough daylight. Relatively shallow floor plate of the building helped in daylighting.
- Energy efficient lighting: LEDs and T5 were used.
- Energy efficient cooling system: A centralised high efficiency water-cooled chiller (COP: 5.8) was implemented for air-conditioning the building. Given the water scarcity in Jaipur, a sewage treatment plant (capacity: 15 m^3/d) was installed and treated waste water is used for the cooling towers.
- Solar photovoltaic (SPV) system: A 45kW$_p$ grid-connected roof-top SPV system with net metering is installed to meet part of the building energy requirement.

The building became operational in 2015 and has been monitored for a year. A comparison of the monthly EPI for the simulated case and actual performance. Energy simulation showed that EPI of the building was 77 kWh/m^2/year before the technical assistance; it was reduced to 53 kWh/m^2/ year after integrating energy efficiency features and the monitored EPI of the building is 43 kWh/m^2/year.

This building clearly demonstrates the benefits of EETC buildings. In this case, the intensive and continued technical assistance was the key to the strategies being implemented. This support also demonstrated a better engagement and understanding of the concepts of EETC design by the project team from the state department.

DESIGN GUIDELINES

A detailed guideline document to assist architects and designers in the design of EETC public buildings has been developed for Karnataka. Similar documents are under development for Rajasthan and Andhra Pradesh. The guideline document for Karnataka has following main chapters i) basics of integrated design process ii) climate analysis and thermal comfort iii) climate responsive design iv) efficient cooling systems v) integration of solar energy. The document provides detailed analysis of the four types of climates which are found in Karnataka. In addition, the design guidelines also recommend changes in the standard design process followed by the PWD to ensure that the architecture and engineering departments work coherently since early design phase to develop an energy efficient building design. The publication was developed in close collaboration with the state PWD and was reviewed by PWD before publication. A training seminar was also conducted for the PWD architects and engineers after the release of the document. The design guidelines were released in September 2016, the project has plans to get a feedback from PWD on its impact after completion of one year of its release and plan further actions.

CONCLUSION

Based on the experience gained during the project, the project team has identified some of the key elements of a comprehensive strategy for mainstreaming energy efficient building design practices in state PWDs. Some of the key features are described below:

Need for a comprehensive capacity building strategy

A comprehensive capacity building strategy is needed for mainstreaming.

i. Expanding the reach of capacity building programmes: The project focussed on building capacities of the design teams (PWD architects and designers) posted at the PWD headquarters. For mainstreaming, the capacity building effort needs to be expanded to cover: a) private sector architect and engineer consultants engaged by PWDs for design work (as more and more design work is being outsourced by PWDs); b) PWD site engineers posted in districts and civil contractors responsible for the construction of the public buildings (as often the design team based in PWD headquarters has limited role in the construction); c) Apart from PWD, there are many other departments which are responsible for public building construction in states e.g. in case of Andhra Pradesh, there are a group of construction departments such as, Road & Buildings Department, Panchayati Raj, etc.
Awareness generation activities should cover key building user or client departments as well. They

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should be made aware about importance and advantages of EETC buildings. The expanded group of stakeholders for capacity building are shown in **Figure 1**.

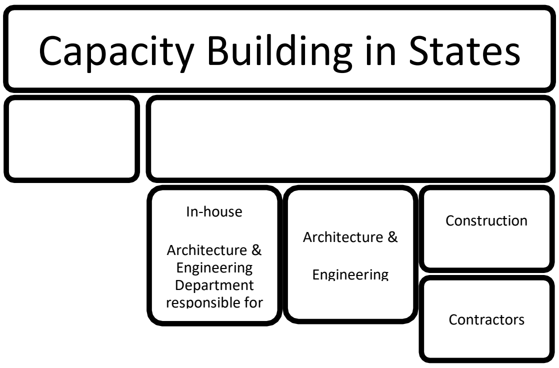

Figure 1: Expanded group of stakeholders to be included in capacity building programmes in states

ii. In-house trainers: The capacity building activities undertaken by an external agency (e.g. this project) are usually one-time activities. For sustaining the capacity building exercise an in-house pool of trainers is needed. During the interactions, a pool of PWD architects and engineers having good understanding of energy efficient buildings were identified. The future efforts should focus on developing a mechanism where these professionals are trained and take up the role of in-house trainers.

Need for systemic changes in PWDs

The experience also indicates that certain systemic changes are needed in PWDs for mainstreaming.

i. Adoption of Integrated Design Process: One of the barrier in designing energy-efficient buildings lies in the process followed by state agencies for designing buildings. While working with one of the state PWD, it was noticed that the architecture and engineering departments work independently of each other. The architectural design is first prepared by the architecture department which is then forwarded to the engineering department for MEP design, tendering and construction. The architecture team have very limited role once the architecture design of the building has been completed. One of the key recommendations made by the project team was to follow the Integrated Design Process (IDP) approach so that the architecture and the engineering departments work together in the initial design stage. This process will require certain procedural changes in the government process.

ii. Revision of State Schedule of Rates (SOR): When a building comes to the architecture department from a client department for design, it comes with an approved budget based on thumb rules. It is difficult to get this budget revised on the higher side for an energy-efficient design and hence the energy-efficient design should be implementable within the approved budget. This is particularly true of the template buildings. The only way to ensure this is to include energy efficient building materials/systems in the Schedule of Rates.

Reaching out to public through exemplary public buildings

Because of the high footfalls, well-designed public buildings could be used to educate public about the design strategies and benefits of EETC buildings. Use of posters, audio-visual capsules, digital display of building performance, guided tours are some of the ways to reach out to public. Such an approach on a limited scale was tried in the state forest department head quarter building at Jaipur and the results were encouraging.

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Table 1: Building projects that were supported for improvement in template design

State	**Rajasthan**		**Karnataka**	
Building type and location	**Distt. Court, Banswara**	**Rehabilitation Centre for mentally retarded Women & Children, Barmer**	**Distt. Court, Bengaluru**	**Distt. Office, Bijapur**
Built-up Area (m^2)	7,900	Acad.: 21,130 Hostel: 12,400	5,500	12,000
No. of floors	G+1	Acad.: G+1 Hostel: Ground Floor	G+1	G+2
Climate Zone	Hot-Dry	Hot-Dry	Temperate	Hot-Dry
Composition	5 Court halls & Judges Chambers	Acad.: Therapy Rooms, class rooms, etc	4 court halls, 1 mini court room & Judge’s chamber	Offices

EETC strategies	• Revised Configuration of rooms around courtyard for better daylighting & ventilation • Change in window glass specifications, introduction of light shelves, increase the WWR to 26% and use of external movable shading (chiks) on the east & west facades • Use of insulation in walls and roof to bring down the U-value to 0.44 $W/m^2.K$ and 0.40 $W/m^2.K$ respectively • Night cooling and exposed structure	• The building massing of the academic block was revised to reduce heat gains, improve daylighting and natural ventilation • Fixed shading of different sizes was suggested for different facades. In addition external movable shutters were recommended for eastern and western facades • Rearrangement of room layouts to ensure adequate daylighting on working spaces. • Use of roof and wall insulation to lower the U-value • Use of hybrid cooling systems	• Swapping of dead spaces such as toilets and stores with court rooms or judge's chambers for better daylighting and ventilation • Night ventilation and window operating schedules to cool the building structure • Use of water cooled split air-conditioners for judge's chambers	• Change in orientation of building for longer facades to face absolute N-S • Use of roof and wall insulation to lower the U-value • Redesigning of windows to ensure better daylight and natural ventilation • Design of external movable shutters in the corridors on the eastern and western facades • Rearrangement of a few spaces for better daylighting • Use of water cooled split air-conditioners in a few rooms

	for natural ventilation • Use of water cooled split air-conditioners and indirect evaporative cooling	(evaporative cooling with ventilation chimneys) for the hostel block along with fixed louvers in the courtyard • Use of solar water heaters for hostel • Use of occupancy sensors for the hostel block		