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Case study of GRIHA rated institutional buildings

Examining green building features and building energy systems to facilitate of GRIHA rated projects to facilitate design for all.

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Abstract

Case studies serve as an important education tool for students and practitioners, and allow for future project planning, and data collection ahead of time. This paper documents building envelope and energy system design strategies implemented by two government GRIHA rated institutional buildings in New Delhi. Project details include building specifications (building size, level of performance as per GRIHA rating, year of construction and occupancy, and cost of the project), and green building features (architectural design, building materials (envelope and interiors), and building energy systems (visual, thermal, and other systems).

Both projects are in the composite climate zone and provide useful insights into the prevalent sustainability linked practices in the Indian construction sector.

KEYWORDS*::** ***Case studies, GRIHA rating, institutional projects

1. Introduction

GRIHA (Green Rating for Integrated Habitat Assessment) rating framework is an evaluation tool for measuring and rating a building's environmental performance. It facilitates design and evaluates a project through its life cycle including pre-construction, building planning and construction, and operation and maintenance stages. In addition to reducing the greenhouse gas emissions from buildings, GRIHA helps projects to optimise electricity consumption while meeting comfort requirements, reduce dependence on fossil fuel-based electricity and reduce stress on natural resources. Other benefits of GRIHA rated buildings include direct health benefits like reduced air and water pollution.

GRIHA rated building case studies are instrumental in providing information for enhanced understanding, increasing the body of knowledge, and disseminating information on design strategies around resource efficiency in the built environment. They often outline new solutions to meet various building and energy codes, which students and architects may attempt to understand and advance for their own academic or real-life projects. While several case study publications by the Central Public Works Department (CPWD)[1]-an authority within the Ministry of Housing and Urban

[1]https://cpwd.gov.in/Publication/Solar_Power_Booket_Seminar.pdf;https://cpwd.gov.in/Publication/Architectural_Footprints_of_CPWD.pdf;https://cpwd.gov.in/Publication/Architectural_Footprint_10_Sep.pdf; https://cpwd.gov.in/Publication/IGDBooklet.pdf

Affairs, Government of India, GRIHA Council[2] and United Nations Environment Program (UNEP)[3] provide information on the design approach, highlight overall strategies for GRIHA compliance and provide guidance for projects in India- detailed specifications, and examples to help learn and facilitate code compliance is not available. Popular media articles repeatedly publish and highlight the same buildings, which accentuates the need to dissimilate information about green building projects that have not been documented so far.

1.1 Case study selection

Data collection for this research has been covered under the ambit of the Memorandum of Understanding signed between the School of Planning and Architecture, New Delhi and CPWD in2019. Considering that CPWD endorsed GRIHA rating in 2009, it is important to formally publish the achievements in terms of enhanced building performance assessed through GRIHA rating in the decade after its adoption, i.e. between 2009 and 2019. Selection of case study buildings is based on the following parameters:

- ***Minimum 4 or 5 Star GRIHA rated (or provisionally rated) and comply with relevant and applicable Indian codes and standards in composite climate zone.***
- ***Building use to be institutional and project to be operational (day use).***
- ***40% (or more) of the building to be air conditioned.***

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[2]*https://www.grihaindia.org/case-study; http://www.pace-d.com/wp-content/uploads/2016/08/GRIHA-and- Green-Buildings-in-India-%E2%80%93-GRIHA-Council.pdf*

[3]*file:///C:/Users/User/Downloads/-State%20of%20Play%20for%20Sustainable%20Buildings%20in%20India- 2010994.pdf*

- ***Built up area to be more than 20,000sqm (i.e., project eligible for seeking environmental clearance).***

As per list of GRIHA rated projects available on the GRIHA website (accessed in August 2020), there are 155 GRIHA pre-certified/ provisionally certified/ certified CPWD projects in India. 17 of these CPWD projects (institutional and residential) are in Delhi NCR, 14 of which are institutional projects complying with various formats of GRIHA including GRIHA, GRIHA EB (existing building), GRIHA LD (large development), SVA (simple, versatile, affordable) GRIHA and TERI GRIHA (GRIHA v1 2007).

Four projects that meet the above-mentioned criteria are shortlisted below:

- ***Indira Paryavaran Bhawan (IPB), Jor Bagh (5-Star GRIHA Provisional Rating)***
- ***Lecture Theatre and Lab Complex at IIT Delhi, New Delhi (4-Star GRIHA Provisional Rating)***
- ***Punjab National Bank Head Office, Dwarka (5-Star GRIHA Provisional Rating)***
- ***Supreme Court Extension, Pragati Maidan (5-Star GRIHA Provisional Rating)***

Since the Indira Paryavaran Bhawan at Jor Bagh has been documented extensively, the details of this project have been excluded from this paper. Furthermore, the Supreme Court Extension project comprises five buildings (including residential) and is not a single building like other projects, and hence it was also excluded from the final case study selection. To maintain anonymity of the projects, shortlisted case studies have been named 'Project 1' and 'Project 2' for description in this paper.

2.Case studypresentation

The following process has been adopted for data collection.

- ***Review of primary documents (for construction and operation) including final agreement between CPWD and contractor, final bill under CPWD agreement and tendered Bill of Quantities from CPWD.***
- ***Preparation of questionnaires for green building consultants.***
- ***Interviews and discussion with concerned CPWD officials.***

Broad categories under which the specification and cost data has been collected are as follows:

1.General project details

2.Envelope	**4.Heating, ventilation, and air conditioning**
○ **Wall** ○ **Fenestration** ○ **Roof**	○ **Total tonnage** ○ **HVAC design parameters** ○ **Type and cost of HVAC system**
3.Internal lighting	**5.Electrical system**
○ **Connected lighting load** ○ **Type and cost of lamp, fixtures, and ballasts** ○ **Lighting controls**	○ **Total connected load** ○ **Type and cost of transformer** ○ **Capacity and cost of DG sets** ○ **Building management system (BMS)**

Building	**Built-up Area**	**Total Project Cost**	**Date Completed**	**Salient Features**

Project 1	**45,761m^2** • **G+4** • **1 basement**	**Rs.115cr (Rs. 25,130/sqm)** • **Civil: 100.6cr (87.47%)** • **Elec.: 3.35cr (291%)**	**2015**	• **GRIHA 4 Star (provisional)** • **North-South orientation** • **WWR= 23.5%** • **Daylight integration** • **Strong shading strategy** • **EPI: 59.06kWhr/m2/annum** • **5MWp solar system on campus** • **CFL and T5 fixtures** • **Flyash based material**
Project 2	**76,188m^2** • **G+5** • **3 basements**	**Rs.405cr (Rs. 53,160/sqm)** • **Civil: 137cr (33.82%)** • **Elec.: 66cr (16.29%)**	**2017**	• **GRIHA 5 Star (provisional)** • **WWR= 35.4%** • **Daylight integration** • **EPI: 43.5kWhr/m2/annum** • **202KWp rooftop solar PV** • **LED fixtures+ sensors** • **Pervious paving** • **Flyash based material**

***Table 1*: Key information about the case studies; Source: Compiled by Priyanka Kochhar**

2.1Project 1

The first case study comprises a multi-storey (B+G+5) building with composite structure of RCC and structural steel. It encompasses lecture halls with 500, 300, 150, 60 and 30 seating capacities, laboratories for physics, chemistry, biology, applied mechanical, computers, humanities, and design studio along with an auditorium with 500 seats, and conference rooms. The building is divided in 5 blocks, A, B, C, D & E by construction/ seismic expansion joints and has been designed to accommodate students.

The whole building is on raft foundation of RCC and designed as compact building to save energy. It is centrally air conditioned

and meets GRIHA 4 Star compliance on energy and other standards. Select features of the building are as follows:

- **RCC framed structure with shear walls**
- **Cavity walls and double-glazed glass**
- **Aluminium doors and windows**
- **External dry cladding in sandstone**
- **Fire resistant structural glazing and aluminium composite panel**
- **Vitrified tile in labs, kota stone in corridor and granite in foyer**
- **Acoustic treatment of lecture halls**
- **Fire alarms, sprinklers, and wet risers**
- **Adequate number of lifts in three blocks**
- **Centrally air-conditioned classrooms and labs**
- **Smart classrooms with projectors and audio video facilities**

Image 1: Project 1, New Delhi; Source: Priyanka Kochhar, assisted by Kanika Trivedi

Block A comprising central foyer and entry area has a double height (10.75m) opening. This block is circular in shape and the

RCC structure has circular beams that are curved in plan along with circular columns (10.75m height).

Block B is circular in shape and comprises the lecture halls. Due to the long spans of lecture halls (24.3mx21.15m), structural steel plate girders that rest on shear walls have been provided. Built up sections of structural steel are used as primary and secondary (beams) members. Primary members (plate girders) are supported by RCC shear walls. It consists of 3 lecture halls of 300 capacity on the ground floor, 4 lecture theatres of 150 capacity and student lounge on the first floor, 4 lecture theatres of 150 capacity and student lounge on the second floor, 4 lecture theatres of 150 capacity and 3 classrooms of 60 capacity on the third floor, and 9 classrooms of 60 capacity and 9 classrooms with 30 capacity on the fourth floor.

Block C is the laboratory block which is an RCC structure in rectangular shape (45.08mx17.65m). the height of each floor is 4.2m, where the main structural members are beams and columns. There are 5 laboratories on each floor.

Block D has a composite structure of structural steel and RCC. Due to the long span (42.04mx20.74m), height (8.54m) and circular shaped auditoriums, built up sections of structural steel have been provided as primary and secondary members. Plate girders are supported by shear walls. It comprises an auditorium of 500 capacity on the ground floor (up to mezzanine floor roof slab), an auditorium of 500 capacity on first floor (up to second floor roof slab) and 2 laboratories on the third floor.

Block E consists of ramp area in between C&B blocks and B&D blocks.

2.1.1 Building specifications

Built on a 19,690sq m site inside the 320 acres IIT Delhi campus, the Lecture Theatre and Lab Complex has been designed to accommodate a floating occupancy of 2200 students and faculty. It has a total built up area of 45,761sqm out of which about 40% is air conditioned. Building envelope U-values (W/m2K) were as follows: Wall (thick stone cladding+230mm flyash brick+115mm flyash brick+plaster): 0.766; Window (i.e. glazing in air conditioned area): 1.9 with VLT of 0.39 and SHGC of 0.28; Roof assembly (RCC slab with 50mm fibre glass wool +150mm brick coba): 0.596.

The building design ensures daylight to 51.6% of occupied areas and artificial lighting is provided using T5 lamps with electronic ballasts and CFLs. The LPD achieved is better than requirements of the Energy Conservation Building Code (ECBC) requirements. The HVAC systems have been designed to maintain a room temperature of 24 ± 1°C. The total cooling load is 550TR, where 3x275 TR variable air volume with water loop chiller system (2 working+1 standby) have been used. The total load of electrical systems is 1271kW, and an integrated building management system is also provided.

2.1.2 Green features of the building

Building material

- ***Brick work for walls: The outer walls of the building comprise a cavity wall made of 230mmflyash brick and 115mm flyash brick clad with thick stone on the external side and plaster on the internal side, resulting in U -value of 0.766 W/m2K (ECBC 2007 requirement: 0.44 W/m2K).***

- ***Wood and PVC work for fenestrations: 24 mm thick double glazed hermetically sealed windows are provided in the North West/ South West sides of the building. Sun louvers are also provided to reduce the cooling load. Glazing U-value for air conditioned area: 1.9 W/m2 °K and for common/ non air conditioned area is 5 W/m2 °K.Glazing Solar Heat Gain Coefficient (SHGC) for air conditioned area is 0.28 and for common/ non air conditioned area is 0.43. Glazing Solar Coefficient for conditioned area is 0.32 and that for common/non-conditioned area is 0.49. the total window to wall ratio is 23.5%. To meet the GRIHA rating requirement the visual light transmittance (VLT) is 0.39.***
- ***Roof: The roof assembly has been provided with reinforced cement concrete slab, with 50mm fibre glasswool insulation and 150mm brick coba.***

Building energy systems

- ***Indoor lighting and control sensors: The lighting system of this building is designed with T5 lamps with electronic ballasts and CFLs to achieve Lighting Power Density (LPD) of : 1.5 W/ ft2 for Lecture Theatre/Classroom; 1.0 W/ ft2 for Equipment Room and 0.5 W/ ft2 for Miscellaneous Areas, and meet ECBC 2007 recommended levels in all spaces.***
- ***HVAC: 40% of the building superstructure is air conditioned and designed for central cooling. The air conditioning load is estimated to be 550 TR for which 3x275 TR variable air volume with water loop chiller system (2 working+1 standby) have been installed.***
- ***Electrical: The total electrical load of the building is 1271kW. Two diesel generator sets (500kVA+750kVA) are***

used for emergency purposes or during power failure. There are three 2000KVA dry type transformer and one 1000kVAtransformers provided on site. Further, UPS power (100kVA) and integrated building management system has been provided.

2.2 Project 2

The second case study project is built on a plot size of approximately 5acres. Designed for about 1650 employees, it covers a built-up area of 76,188m2 across six floors and three basements. About 70% of the superstructure is air conditioned. While it was designed as a net-zero building, the final project has received GRIHA 5 Star (provisional) rating.

Image 2: Project 2, New Delhi; Source: Priyanka Kochhar, assisted by Kanika Trivedi

2.2.1 Building specifications

The building is composed around the central axis that emerges from the metro station through the park into the centre of the site. Bridged floors across the axis are created at ground and top levels for corporate floor, café and multipurpose halls. The opening up of the entire centre of the building breaks down the

scale of the large building into smaller elements. There is a six-storey high circular glazed cylinder at the end of the axis that accommodates the PNB gallery, VIP lounges and special conference rooms. Opening of the centre create a strong venturi effect that draws the south-west winds into the atrium, making natural cooling effective for several months through the year.

2.2.2 Green features of the building

Building material

- ***Brick work for walls: The outer walls of the building are double wall units with extruded polystyrene as insulation in between. The outer walls are made of 200mm AAC (Autoclaved Aerated Concrete) block and the inner walls of 100mm AAC block. 30mm extruded polystyrene is provided between the outer and inner walls, resulting in U -value of 0.39 W/m2K (ECBC 2007 requirement: 0.44 W/m2K).***
- ***Wood and PVC work for fenestrations: All windows in the building are Un-plasticised Poly Vinyl Chloride (UPVC) windows with double glazed units. To meet the GRIHA rating requirement of heat load reduction, the U-value of external window assembly is 1.48 W/m2K (ECBC 2007 requirement: 3.3 W/m2K). The visual light transmittance (VLT) is 0.49. With a Solar Heat Gain Coefficient (SHGC) of 0.22 of double glazing and appropriate shading design, achieved SHGC of fenestration is 0.23.***
- ***Roof: The building has a unique roof design. The roof plane is broken into four panels, comprising two lower side panels that reflect the slightly tilted geometry of the building plan below, and two raised panels that cover the atrium. The roof assembly has been provided with 250mm reinforced cement concrete slab, with 75mm XPS***

insulation and tiles finish to achieve U value of roof assembly is 0.31 W/m2K (ECBC 2007 requirement is 0.41).

Building energy systems

- ***Indoor lighting and control sensors: The lighting system of this building is designed with LEDs and sensor controls, to achieve Lighting Power Density (LPD) of 0.60W/ft2 for office floors and meet ECBC 2007 recommended levels in all spaces. Daylight sensors (lux level sensors) and occupancy (motion) sensors have been installed in the building.***
- ***HVAC: 69% of the building superstructure is air conditioned and designed for central cooling. The air conditioning load is estimated to be 660 TR for which three water cooled chillers (2 working + 1 standby) of 375 TR each and one 100 TR chiller have been installed.***
- ***Electrical: The total electrical load of the building is 2195kW. Electricity is sourced from BSES Rajdhani Power Limited. Diesel generator sets are used for emergency purposes or during power failure. 200kWp solar rooftop plant has also been installed. There are three 1000KVA dry type transformer and four DG sets with rating 2x1000kVA (gas based), 500kVA (diesel based) and 380kVA (diesel based) capacity. Further, UPS power has been provided to support critical service such as emergency lighting, power points for workstations, security system and building automation system and server room. An integrated building management system to control and monitor the building's mechanical and electrical equipment such as AHUs, TFAs, chillers and electrical system has also been provided.***

3. Discussion

GRIHA is based on nationally accepted energy and environmental principles that assesses a building out of thirty-four criteria, and awards points on a scale of hundred. The criteria are divided into 'applicable' and 'selectively applicable' categories, where certain criteria and sub-criteria of 'applicable' category are mandatory for the project to achieve GRIHA rating.

Table 2 below summarises key GRIHA criteria to optimise electricity consumption while meeting comfort requirements. GRIHA facilitates implementation of relevant codes such as the Energy Conservation Building Code (ECBC), National Building Code (NBC), and Special Publication (SP) 41 of Indian Standard (IS) for resource efficiency through design that results in abatement of carbon emissions from the built environment.

Table 2: GRIHA (2007) criteria 13 & 14 incorporating relevant codes and standards; Source: GRIHA Manual Volume 1: Introduction to National Rating System, adapted by Priyanka Kochhar

Criteria	Description	Points	Applicability	Relevant codes and standards incorporated
Criterion 13	*Optimize building design to reduce conventional energy demand*	*8*	*Mandatory*	*ECBC 2017 NBC 2005 Part 8/ Section 1-3 SP-41 – 1987 Section 2, Part 7 SP-41 – 1987 Section 2, Part 7*
Criterion 14	*Optimize energy performance of building within specified comfort limits*	*16*	*Partly mandatory*	*ECBC 2017 NBC 2005 Part 8/ Section 1-3*

GRIHA rated projects described above follow mandatory provisions ECBC for air-conditioned buildings. The projects also meet the prescriptive shading norms of ECBC, provide daylight, avoid over design of artificial lighting, and reduce energy performance index from GRIHA benchmark by 10-30%. Summary of building envelope specifications of the two case study buildings is provided in Table 3 below. Both projects meet various GRIHA and ECBC requirements.

Table 3: Case study building envelope specifications; Source: Compiled by Priyanka Kochhar

Envelope	Wall	Glazing	Roof
	• Thick stone cladding+ 230mm flyash brick+ 115mm flyash brick+ Plaster • U-value: 0.766 W/m2 K	• U-value of glazing for air conditioned area: 1.9 W/m2 °K • VLT: 0.39 • SHGC: 0.28	• RCC slab+50mm fibre glasswool+ 150mm brick coba • U value of roof assembly: 0.596 W/m2 K
	• 200mm AAC Block + 30mm rockwool+ 100mmm AAC Block • U -value 0.39 W/m2K	• U-value of external window assembly: 1.48 W/m2K • VLT: 0.49 • SHGC: 0.22	• RCC slab+ 75mm XPS+ tiles • U value of roof assembly: 0.31 W/m2K

Details of building energy systems including lighting, air conditioning and electrical systems are provided for both projects in Table 4 below.

	Lighting	Heating, Ventilation & Air Conditioning	Electrical Systems
Project 1	• Daylight integration (76.6%occupied areas daylit) • LEDs • Daylight/lux level sensors • Occupancy/motion sensors • LPD: Better than ECBC requirement •7% of total energy demand	• Room temperature of 26 ± 1°C • 69% superstructure air conditioned • Cooling load: 660TR 1. 3x375 TR water cooled chillers (2 working+1 standby) •84% of total energy demand	• Total load: 2195kW • Transformers: 3x1000kVA dry type • DG sets: 4 (2x1000kVA gas based+ 1x500kVA diesel based+ 1x380kVA diesel based) • UPS • Integrated building management system
Project 2	• Daylight integration (51.6%occupied areas daylit) • T5 lamps with electronic ballasts • CFLs • LPD: Better than ECBC requirement •25% of total energy demand	• Room temperature of 24 ± 1°C • 40% superstructure air conditioned • Cooling load: 550TR 1. 3x275 TR variable air volume with water loop chiller system (2 working+1 standby) •16% of total energy demand	• Total load: 1271kW • Transformer: 1000kVA +3x2000kVA • DG sets: 500kVA+750kVA+ •UPS: 100kVA • Integrated building management system

Table 4: Case study building energy system details; Source: Compiled by Priyanka Kochhar

4. Conclusion

Descriptive case studies of GRIHA rated institutional projects highlighting design strategies to optimise electricity consumption while meeting comfort requirements are valuable contribution to academic literature on resource efficiency in the built environment. The above case studies which help link envelop and energy system design to ECBC and GRIHA compliance are especially useful to students and practitioners for knowledge enhancement and future project planning. Additionally, published case studies provide information that lead to advances in research and improve level of resource optimisation achieved in buildings.

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