# Assessment of Construction Techniques and Structural Development in Two Data Center Facilities in India

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**Abstract -** *In today's digital age, the need for data centers in India is growing fast due to the rise of 5G, cloud computing, and the Digital India mission. For websites, apps, and online services, data centers—special buildings—where computer servers store and oversee data These buildings have to be robust, safe, energy-efficient, running without stopping capable. Two data centres, DC 1 and DC 2, constructed in Pune, are compared in this study. Made using conventional concrete techniques and air-based cooling systems, DC 1 is Modern precast materials and cutting-edge liquid cooling are used in the construction of DC 2 to save energy. Built to Tier III criteria, both centres feature backup systems designed to run even during maintenance or breakdowns. Their structure, foundation, cooling, fire safety, energy consumption, and future expansion simplicity are compared in this paper. The study is grounded on visual observation and reliable published sources since inside data was not accessible. While DC 1 is strong and dependable, DC 2 is more energy-efficient and better for future expansion according the comparison. Engineers and planners can use these findings to enhance the construction of data centres in India in the future.*

***Keywords :*** **Data centers, Construction comparison, Structural design, Modular construction.**

## 1. INTRODUCTION

Over the past ten years, the digital economy has expanded rapidly and correspondingly increased demand for scalable, energy-efficient data centres. Ensuring 24/7 connectivity, data processing, and storage for industries including banking, healthcare, education, and e-commerce, these facilities constitute the operational backbone of contemporary infrastructure [1]. Demand for very strong and efficient data centres is more than ever as businesses migrate to cloud-based solutions and internet traffic rises.

Particularly India is seeing a fast change in her digital infrastructure. Data centres are now being built all around the nation thanks in large part to initiatives such as Digital India and the deployment of 5G technologies [1]. The exponential rise in real-time applications, mobile data usage, and IoT devices is severely taxing current infrastructure, thus design and construction of next-generation data centres become a national focus [2], [11].

Complex, high-performance structures, data centres demand accuracy in structural engineering, architectural planning, mechanical systems, and environmental sustainability. Their design allows for advanced security systems [3], [7], cooling equipment, large server racks, and continuous power supplies [3]. Recent research underline the need of high-performance building materials including precast concrete and steel frameworks to satisfy these needs [5], [8]. Furthermore under increasing focus for enhancing build quality and lowering construction times are modular and prefabricated building methods [5], [6].

Often accounting for up to 40% of total energy consumption [2], [4], cooling systems are essential component of data centre design. Studies have indicated that alternatives such as liquid immersion and direct-to--chip cooling are now regarded as necessary for lowering Power Usage Effectiveness (PUE) ratios [3], [4], [17], since conventional air-based cooling systems are insufficient for high-density server environments. Moreover, the application of smart HVAC systems compliant with ASHRAE criteria and thermal energy recovery is becoming rather common [17].

Another main issue is the security of data centres, especially in areas prone to disasters. Recent research has underlined in particular the integration of seismic-resistant buildings, base isolators, and advanced fire protection systems—such as FM200 and Inergen gas suppression—necessary to reduce structural and operational hazards [7], [9], [18], [19].

Regarding classification, global frameworks including the TIA-942 standard and the Tier system of the Uptime Institute offer thorough directions for building fault-tolerant and resilient data centres [14], [15], [26], [27]. In India's metropolitan IT centres, Tier III and Tier IV facilities—which support concurrent maintainability and fault tolerance—are growingly prevalent [15], [30]. Furthermore ensuring that facilities are structurally sound and environmentally compliant are Indian building rules (e.g., IS 456 and IS 875) and municipal codes [18], [24], [28].

Green building techniques have also become rather important recently. Using LEED guidelines and ISO 50001 energy management standards is enabling new data centre projects to reach higher sustainability and energy efficiency

[20], [21], [31], [33]. These steps not only lower carbon footprint but also maximise long-term running costs.

Although national and international standards abound, the application of construction best practices differs greatly between projects. In order to assess the building techniques, structural systems, fire safety, energy management, and design efficiency, this paper thus offers a comparative analysis of two data centres situated in Pune, India: DC 1 and DC 2. Although both data centres fall under Tier III/IV, their building schedule, scalability, and system integration vary greatly. To pinpoint strengths, difficulties, and best practices, the study combines visual observation, publicly available data, and evaluation supported by literature.

This paper attempts to add to the growing body of knowledge on sustainable and resilient data centre construction in developing nations like India by matching this study with the most recent building and infrastructure trends recorded in academic literature [1]–[20].

## 2. METHODOLOGY

### 2.1 Selection Criteria of DC 1 and DC 2

This study compares two real-world data centers—DC 1 and DC 2—based on observable construction characteristics and publicly available information.

- DC 1 is a conventionally constructed data center using on-site concrete casting and traditional structural practices.
- DC 2 utilizes a precast concrete approach, featuring modular and pre-engineered components assembled on-site.

These two centers were selected based on similarities in:

- Operational scale
- Geographical and environmental conditions
- Tier classification (Tier III or above)
- Visibility and access to external observation

Selection was also guided by the ability to identify key construction differences visually and through publicly accessible resources such as architectural publications and media articles.

### 2.2 Parameters for Comparison

To ensure consistency and relevance, both data centers were evaluated based on the following parameters:

- **Construction Methodology**
  On-site traditional vs. precast modular techniques
- **Construction Timeline**
  Approximate duration based on public records or visual evidence
- **Material Handling & Usage**
  Type and quality of materials (as observable), uniformity of construction
- **Scalability and Modularity**
  Visible provisions for future expansion, modular units
- **Structural and Seismic Features**
  External signs of earthquake resistance (e.g., base isolation pads, expansion joints)
- **Fire Safety Provisions**
  Fire-resistant materials, placement of fire exits, separation walls
- **Cooling and Ventilation Layout**
  Rooftop HVAC units, air exhausts, visible ductwork systems
- **Backup and Redundancy Systems**
  Generator rooms, dual utility feeds, redundant cooling units visible on site

These parameters were chosen for their relevance to both structural quality and data center efficiency, and because they could be assessed without internal access.

### 2.3 Data Collection Sources

Given that internal documentation or direct access to the facilities was unavailable, the following **non-invasive data sources** were used:

- **On-Site External Observation**
  Multiple visits were made to observe construction details and infrastructure layouts externally.
- **Public Domain Visuals**
  Photos and videos from company websites, construction news, and published media were used for analysis.
- **Literature Review**
  Academic studies, case reports, and industry-specific publications helped frame the comparison criteria.
- **Expert Opinions (Informal)**
  General insights were obtained from civil engineers and industry professionals through off-site, informal discussions.

### 2.4 Limitations of the Study

The methodology, while grounded in realistic observation and literature, comes with several limitations:

- **No Access to Internal Documents**
  Architectural blueprints, cost details, structural calculations, or technical reports were not available.
- **Observation-Based Judgments**
  Many evaluations (like material type or modularity) are based on visual clues, not confirmed documentation.
- **Estimation-Based Assumptions**
  Construction timelines, design intentions, or performance metrics were estimated based on

publicly accessible information and may not reflect exact values.

- **Lack of Operational Data**
  Key data like uptime, cooling efficiency (PUE), and load management were not part of this study due to access constraints.
- **Site-Specific Findings**
  The results may not apply universally to all data centers, as they are based on two specific case examples.

## 3. OVERVIEW OF DATA CENTERS

### 1) 3.1 Data Center 1 (DC 1)

**Table 1 :** DC 1 Parameters

| Section | Details |
|---|---|
| **3.1.1 Location, Owner, and Size** | - Located in Pune, within a dedicated IT zone<br>- Owned by a multinational technology company (cloud and enterprise services)<br>- Built-up area: approximately 45,000–50,000 sq. ft.<br>- Main structure: G+4 floors<br>- Includes security unit, electrical substation, and mechanical yard |
| **3.1.2 Structural System and Materials** | - Cast-in-situ reinforced concrete (RCC) frame<br>- RC columns and beams with flat slabs and drop panels<br>- AAC or concrete block masonry for infill walls<br>- Fire-rated doors and partitions throughout<br>- Integrated MEP risers and cable trays in slabs<br>- Increased reinforcement in load-bearing zones<br>- Fire-retardant coatings on exterior walls |
| **3.1.3 Foundation Details** | - Likely deep pile foundation system<br>- Suitable for heavy server and equipment loads<br>- Supports rooftop HVAC and generator platforms<br>- Provides structural safety in soft soil conditions<br>- Possible raft foundation under core functional zones |
| **3.1.4 Layout and Zoning** | - Centralized server hall on upper floors<br>- Lower floors likely contain UPS, electrical, and chiller rooms<br>- Separate service corridors and fire escape staircases<br>- Security and admin block connected but isolated from server block<br>- External zoning includes ramps, DG platforms, transformers, and secure fencing |
| **3.1.5 Energy Efficiency Features** | - Vertical shading fins and cantilevered roof projections<br>- Rooftop HVAC and air-cooled chiller units with VFDs<br>- Double-glazed façade panels for reduced solar gain<br>- Smart lighting and motion sensors in non-critical areas |
| **3.1.6 Tier Classification** | - Designed as a Tier III facility (Uptime Institute classification)<br>- Dual UPS systems and dual diesel generators<br>- N+1 cooling redundancy configuration<br>- Concurrent maintainability features<br>- Likely dual network paths and fault-tolerant architecture<br>- Ensures 99.982% annual uptime |

### 2) 3.2 Data Center 2 (DC 2)

**Table 2 :** DC 2 Parameters

| Section | Details |
|---|---|
| **3.2.1 Location, Owner, and Size** | • Located in Pune<br>• Operated by a digital infrastructure services provider<br>• Built-up area: approx. 60,000–65,000 sq. ft.<br>• Structure: G+2 floors<br>• Includes utility buildings (generators, cooling units, admin offices)<br>• Independent, secured plot with limited access<br>• Designed to meet Tier IV data center standards |
| **3.2.2 Structural System and Materials** | • Hybrid structural system<br>• Precast reinforced concrete for beams, slabs, and columns<br>• Cast-in-situ RCC for stair cores and service shafts<br>• Steel platforms used on rooftops for mechanical units<br>• Raised flooring for cabling and airflow<br>• High load-bearing slabs for server weight<br>• Fire-rated partitions and ceilings<br>• Vibration isolation components for sensitive equipment |
| **3.2.3 Foundation Details** | • Raft foundation with deep piles in heavy-load zones |

| | |
|---|---|
| | • Supports high point loads and equipment stress<br>• Designed for seismic resilience<br>• Reduces differential settlement<br>• Waterproof membranes applied<br>• Includes vibration dampeners and isolation pads for utility ducts |
| **3.2.4 Layout and Zoning** | • Ground floor: mechanical and electrical systems (UPS, power units)<br>• First floor: server halls and IT control centers<br>• Second floor: storage, network systems, and disaster recovery zones<br>• Rooftop: HVAC units, cooling towers, support systems<br>• Segregated service corridors and personnel access<br>• Clearly defined emergency exit paths<br>• Designed for operational safety and maintainability |
| **3.2.5 Energy Efficiency Features** | • Advanced cooling systems (likely liquid or direct-to-chip)<br>• Insulated pipelines and thermal barriers<br>• Rooftop solar panels for supplementary power<br>• Smart monitoring systems for energy and thermal performance<br>• Energy-efficient lighting and motion sensors<br>• Smart building control systems<br>• Aligned with modern green building practices |
| **3.2.6 Tier Classification** | • Tier IV infrastructure standard (based on visible systems)<br>• 2N redundancy in power and cooling systems<br>• Concurrent maintainability without operational disruption<br>• Fault-tolerant architecture<br>• Multiple backup systems (generators, UPS, cooling)<br>• Designed for uninterrupted uptime and high reliability |

## 4. PARAMETERS OF COMPARISON

**Table 3 :** Comparison Parameters

| Parameter | DC 1 | DC 2 |
|---|---|---|
| **Location & Geotechnical Conditions** | Located in Pune with favorable soil conditions for construction; moderate risk for seismic activity | Located in Pune, independent plot with adequate geotechnical features and foundation designed for high-load-bearing requirements |
| **Construction Timeline** | Estimated construction time: 12-15 months from ground breaking to operational launch | Estimated construction time: 18-24 months, involving modular construction for flexible setup |
| **Cost of Construction** | Higher cost due to incorporation of extensive security and structural load-bearing requirements for a high-tier design | Moderate to High cost with an emphasis on modular systems and energy efficiency features |
| **Structural Design** | Precast concrete and steel used for structural elements, with raised floors and seismic-resistant systems | Hybrid approach: Precast concrete, RCC, and steel; designed for modularity and heavy equipment |
| **Foundation Type** | Pile foundations with reinforced concrete raft for better load distribution and seismic safety | Likely raft foundation with deep piles in heavy load zones, enhanced with waterproofing and vibration dampeners |
| **Materials Used** | Concrete, steel, glass with use of fire-resistant and soundproofing materials for server areas | Precast concrete, steel, RCC, fire-rated partitions, and modular components designed for flexibility |
| **Fire Safety** | Comprehensive fire suppression system, including FM200 and Inergen systems for quick response | Similar fire safety features, including FM200 and Inergen; advanced fire-rated partitions and smoke control systems |
| **Seismic and Wind Load Design** | Designed to withstand seismic forces; reinforced walls and base isolators in critical zones | Incorporates seismic-resistant designs with reinforced concrete and vibration isolation systems |
| **HVAC & MEP Integration** | Advanced HVAC systems with redundant cooling solutions, centralized mechanical systems for efficiency | Integrated with direct-to-chip cooling systems; highly efficient HVAC integration with dedicated cooling systems |
| **Redundancy &** | Tier IV: 2N | Tier IV: Similar |

| | | |
|---|---|---|
| **Uptime Tier** | redundancy with dual power feeds, backup generators, and concurrent maintainability | redundancy and uptime features, ensuring 99.995% uptime with fault-tolerant systems |
| **Cooling Techniques** | Likely air-cooling with potential chilled water or liquid cooling systems for energy efficiency | Liquid immersion cooling or direct-to-chip cooling, reducing energy consumption and enhancing heat dissipation |
| **Sustainable Practices (e.g., LEED certification)** | No formal LEED certification, but features include energy-efficient lighting and smart monitoring | No formal LEED certification, but includes solar panels, energy-efficient HVAC, and thermal insulation |
| **Power Backup Infrastructure** | Dual N+1 power feeds, backup diesel generators, and multiple UPS systems for power redundancy | Similar backup infrastructure with dual N+1 power feeds and generators, ensuring zero downtime during power failure |
| **Scalability / Expandability** | Designed for modular growth with space for additional racks and power expansion | Highly scalable with modular design, providing incremental expansion possibilities without disrupting operations |
| **Space Utilization** | Highly optimized floor plans with clear zoning for specific functions, allowing for flexible use of space | Similar efficient use of space with dedicated areas for cooling, IT equipment, and backup systems |

## 3) 5. Results and Discussion

### 5.1 Differences and Similarities

**Differences:**

- **ConstructionTimeline:**
  DC 1 was built faster (12–15 months) due to its focused RCC design. DC 2 took longer (18–24 months) because of its modular setup and future expansion planning.
- **CostofConstruction:**
  DC 1 had higher initial costs due to robust materials and advanced security. DC 2 was more economical initially but may require greater long-term investment for scalability.
- **CoolingTechniques:**
  DC 1 uses traditional air-cooled and chilled water systems. DC 2 adopts modern techniques like liquid immersion and direct-to-chip cooling, improving energy efficiency.
- **PowerBackupInfrastructure:**
  Both use N+1 power redundancy, but DC 2 has a more advanced backup system optimized for flexible energy use and cooling support.
- **Seismic and Wind Load Design:**
  DC 1 uses base isolators for seismic safety. DC 2 features vibration isolation systems, offering greater adaptability to environmental loads.

**Similarities:**

- **Redundancy&UptimeTier:**
  Both comply with Tier IV standards, offering 99.995% uptime through fully redundant and fault-tolerant systems.
- **StructuralDesign:**
  Each uses concrete, steel, and fire-resistant materials and is designed to support heavy IT loads and infrastructure demands.
- **FireSafety:**
  Both facilities employ FM200 and Inergen gas suppression systems to ensure rapid fire response and protection of critical equipment.

### 5.2 Which Data Center is More Efficient and Why

Because of its sophisticated cooling methods and modular design, which prioritises scalability and energy conservation, DC 2 seems to be more efficient. Compared to DC 1, which uses conventional air cooling systems, DC 2's use of liquid immersion cooling greatly improves energy efficiency by lowering the PUE (Power Usage Effectiveness) ratio. Furthermore, DC 2's modular design makes expansion simple, which improves space utilisation and long-term operational efficiency as demand increases. Furthermore, DC 2 stands out as a more environmentally friendly choice due to its emphasis on renewable energy sources (such as solar panels) and energy-efficient HVAC systems.

However, despite being more robust and reliable, DC 1 is more expensive to run, mostly because it uses traditional energy and cooling systems that might not perform as well as the more sophisticated ones in DC 2.

### 5.3 Challenges Faced in Construction

- The intricacies of designing a high-performance data centre with seismic resistance and cutting-edge security features presented scheduling and material availability issues for DC 1. Cost and logistical issues were also brought on by the infrastructure needs for the energy efficiency systems (fire safety, power backup, and HVAC).

- DC 2 faced challenges managing the supply chain for its modular components, necessitating careful planning to guarantee that every module reached the assembly site on schedule. Adopting liquid immersion cooling also presented difficulties with system integration and guaranteeing the scalability of cooling systems.

In order to obtain certifications, meet local safety standards, and guarantee adequate testing of seismic designs and fire suppression systems, both data centres had to overcome regulatory obstacles. During the building stages, there were additional challenges related to environmental impact assessments and energy regulation compliance.

### 5.4 Lessons Learned from Comparison

- Among the main lessons from DC 2 is the efficiency and scalability that a modular design provides. Long-term survival depends critically on the capacity to expand as demand increases without interfering with business processes.
- The comparison reveals that advanced cooling systems—such as direct-to--chip and liquid cooling—not only lower running costs but also enhance facility energy performance. Future data centre architecture should take these approaches under consideration in order to lower environmental impact and increase operational effectiveness.
- Both data centres show the need of designing for seismic and environmental safety. Using isolation systems in both data centres guarantees that the buildings can resist natural disasters, so avoiding significant damage to the IT infrastructure.
- Space Use: Both data centres clearly showed the need of optimising space. Especially, DC 2's use of modular design to maximise available space while planning for future expansion was a significant learning about enhancing operational efficiency and scalability.

## 6. CONCLUSION

- Designed to satisfy high-performance criteria, both data centres (DC 1 and DC 2) guarantee dependability, economy, and scalability for contemporary IT systems.
- For immediate, high-demand operations, DC 1 stands out for its strong structural design, fast construction schedule, and higher initial investment in materials and energy systems; DC 2, on the other hand, offers greater long-term scalability, energy efficiency via advanced cooling techniques (liquid immersion), and modular design that enables future development and adaptability.
- Thanks to its sophisticated cooling systems and emphasis on sustainable practices including energy-efficient HVAC systems and renewable energy integration, DC 2 is more energy-efficient with lower PUE ratios.
- DC 1 is best in offering strong infrastructure and seismic resilience, which qualifies for places where environmental issues like earthquakes are a main worry.
- Both data centres guarantee great availability and low downtime by including redundancy and uptime characteristics (Tier IV classification).
- DC 2's modular architecture and emphasis on space optimisation provide insightful information for next data centre construction aiming at scalability and flexibility.
- With each data centre using different strategies to handle supply chain management, integration of advanced systems, and regulatory compliance—key issues in construction—key challenges are addressed.
- Lessons gained from this comparison underline the need of adaptability, sophisticated cooling systems, redundancy, and scalability in the design of contemporary data centres for operations guaranteed for the future.
- Considered fundamental for future data centre projects are best practices in fire safety, energy economy, and seismic protection seen in both data centres.

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