CEILING SYSTEMS AS INFRASTRUCTURE

Designing Flexible, Energy-Efficient Data Centres

Network Architectural

Introduction

Australia is currently ranked among the world's top ten data centre markets, with more than 250 operational facilities nationwide and demand continuing to accelerate.[1] Industry forecasts indicate that approximately 175 additional data centres will be required by 2030 to support growth in cloud computing, artificial intelligence (AI) and data-intensive services.[2] This expansion is already reshaping the construction sector, contributing to a significant uplift in commercial activity and pushing the New South Wales construction pipeline to nearly $42 billion in the 2025 September quarter alone.[3]

As data centres scale in size and complexity, design priorities have shifted beyond short-term delivery to focus on long-term operational resilience, energy efficiency and adaptability. Within this context, ceiling systems play a critical but frequently underestimated role. Beyond their conventional function as interior finishes, ceiling systems in data centres operate as part of the building's technical infrastructure, supporting thermal performance, airflow management, service integration and spatial flexibility.

This paper explores the principles of data centre design and examines ceiling systems through an architectural and performance-based lens, considering how specification choices can contribute to efficient cooling, coordinated services and adaptable layouts over the life of the facility.

What is a data centre?

A data centre is a purpose-designed facility that accommodates the physical infrastructure required to store, process and distribute digital information. These facilities house servers, storage systems and network equipment that support critical applications across government, finance, healthcare, research and commercial sectors. Unlike conventional commercial buildings, data centres are defined by their continuous operational requirements, with systems designed to operate 24 hours a day, seven days a week, under tightly controlled environmental conditions.

Fundamentals of data centre design

Data centres are mission-critical facilities where operational continuity and resilience take precedence over conventional architectural priorities. As a result, architectural and building management decisions are driven by performance certainty, coordinated services and the ability to accommodate change without interrupting operations.

Key design principles that underpin data centre performance include:

- **Redundancy:** Critical systems are designed with multiple backup pathways and components to ensure uninterrupted operation in the event of equipment failure or maintenance activities.
- **Predictability:** Environmental conditions, power delivery and airflow must remain stable and controllable to protect sensitive IT equipment and maintain operational reliability.
- **Flexibility and scalability:** Facilities must support future increases in power density, changes in cooling strategies and technology upgrades without requiring major structural alteration or downtime.
- **Energy efficiency:** Rising energy costs, sustainability targets and increasing regulatory pressure have made energy performance a central design consideration.
- **Security:** Physical security strategies typically involve layered access control, surveillance and zoning to protect both the facility and the data it contains.
- **Fire safety:** Systems must be carefully selected and coordinated to mitigate fire risk while minimising potential damage to equipment and maintaining operational continuity.

Cooling as a critical function

Servers and associated IT equipment generate high heat loads during operation and are highly sensitive to temperature fluctuations. If thermal thresholds are exceeded, equipment will progressively throttle performance to reduce heat output, resulting in reduced computing capacity. In extreme cases, systems will shut down entirely to prevent damage.

Cooling systems represent a significant share of a data centre's energy consumption and operating costs. Common cooling solutions include:

- **Raised floor systems:** Cold air is delivered through an underfloor plenum via perforated floor tiles. Common in traditional data centres, this approach supports flexible cabling and air distribution but can incur higher operating costs if airflow leakage and pressure losses are not well controlled.
- **Hot and cold aisle containment:** Hot and cold aisle containment strategies improve cooling efficiency by separating supply and exhaust air. Hot aisle containment (HAC) encloses hot exhaust air and returns it directly to the cooling system, while cold aisle containment (CAC) encloses cold supply air to deliver stable temperatures at equipment intakes and reduce overcooling.
- **Overhead cooling systems:** Cold air is supplied through ceiling-mounted ducts or plenums with high-level return air paths. Increasingly used in newer and modular facilities, this approach can simplify installation, reduce dependence on raised floors and improve access for maintenance and future reconfiguration.

Cooling plant and air delivery systems typically include specialised CRAC (Computer Room Air Conditioner) units, which provide direct expansion cooling. They may also include CRAH (Computer Room Air Handler) units, which distribute conditioned air using chilled water supplied from a central plant.

Liquid cooling technologies are gaining traction in high-density environments, using direct-to-chip or immersion methods to remove heat more efficiently than air-based systems.[4] Their adoption introduces new coordination requirements for building services, including the integration of liquid supply and return lines, enhanced containment strategies and dedicated ceiling zones to manage routing, access and monitoring.

Ceiling systems in data centre design

Ceiling systems form the critical interface between the building structure and the technical infrastructure that supports data centre operation. Positioned at the intersection of mechanical services, electrical distribution, environmental control and spatial planning, ceiling systems influence airflow, thermal stability, service coordination and long-term operational resilience.

In many data centre environments, ceiling systems are based on a structural grid framework comprising interconnected metal components suspended from the primary structure. This typically includes main runners, cross-tees and hangers that create a robust and modular support system.

Unlike traditional commercial ceilings, structural grid systems are designed to carry substantially higher point loads, often in excess of 1,000 kg, allowing them to support overhead cabling, containment systems, lighting, ventilation components and other critical equipment. This load-bearing capacity enables services to be integrated overhead without relying on the building structure for each individual element.

Performance and material considerations

Structural performance

Ceiling systems in data centres must support higher dead and live loads than standard commercial applications. Typical loads include cable trays, containment systems, luminaires, sensors and monitoring devices. Metal ceiling grids and suspension systems are commonly specified for high point loads and dense service integration.

Airflow and cooling coordination

Effective thermal management depends on predictable airflow paths and clearly defined pressure zones. Ceiling systems aligned to the structural grid enable consistent placement of return air paths, diffusers and containment interfaces, supporting hot and cold aisle and overhead cooling strategies.

Flexibility, scalability and integration

Data centres are subject to frequent reconfiguration as equipment densities increase and technologies evolve. Grid-based ceiling systems provide a modular framework that supports incremental change, allowing services to be added, relocated or upgraded within the ceiling zone without major structural intervention. In addition to airflow management, ceiling systems commonly support:

- cable management, including structured cabling and fibre pathways;
- fire safety and suppression integration, coordinating detection and clean-agent systems;
- lighting and security infrastructure, such as luminaires, sensors and surveillance; and
- cleanliness and contamination control, including controlled air infiltration and dust management.

Material selection and panel performance

Ceiling material selection affects durability, fire performance and contamination control. Common options include galvanised steel and aluminium grid systems with metal, mineral fibre or specialised ceiling panels. Panel selection may vary depending on requirements for fire resistance, moisture resistance, acoustic performance or airflow control. Perforated or solid panels are selected based on ventilation and pressure management strategies.

Air leakage control

Ceiling systems form part of the pressure boundary within data halls and directly influence airflow efficiency. Poorly sealed ceilings allow conditioned air to escape into unconditioned zones, increasing cooling demand. Sealed panels and controlled service penetrations are commonly specified to maintain pressure integrity.

Fire resistance and compliance

Ceiling systems must comply with National Construction Code fire performance requirements appropriate to data centre occupancies. Materials are typically non-combustible or fire-rated and must integrate cleanly with sprinkler layouts, detection systems and smoke management strategies.

Seismic performance

Ceiling systems must accommodate structural movement without failure or service disruption. Flexible suspension systems and seismic-rated fixings aligned with the structural grid reduce the risk of collapse and damage during seismic events. In Australia, suspended ceiling systems are typically designed and installed in accordance with AS/NZS 2785 “Suspended ceilings – Design and installation”, with seismic actions determined in accordance with AS 1170.4 “Structural design actions, Part 4: Earthquake actions in Australia”.

Durability, access and operational performance

Data centres are designed for long service lives with frequent access to overhead services. Ceiling systems must tolerate repeated panel removal without loss of alignment or performance. Modular panel layouts aligned to the structural grid, with designated access zones, support maintenance, monitoring and upgrades while minimising operational risk.

Data centre energy demand and regulation

The rapid adoption of AI is reshaping data centre design with direct implications for energy consumption. AI training and inference workloads rely on high-performance computing (HPC) infrastructure, driving a sharp increase in rack power density and heat output. While average rack densities have historically sat around 10–15 kW per rack, AI-driven facilities are now planning for densities of 60–120 kW per rack to support accelerated servers operating in close proximity.[5] As a result, cooling energy is the dominant contributor to total facility energy consumption in AI-focused environments.

This shift is occurring alongside tightening energy performance expectations. Data centres currently account for an estimated five per cent of electricity demand on Australia's power grid, with projections suggesting this could rise to between eight and 15 per cent by 2030.[6] Regulatory pressure is increasing accordingly. For example, since 1 July 2025, all data centres that hold federal government workloads must achieve a five-star NABERS Energy rating (equivalent to a Power Usage Effectiveness of 1.4 or better).[7]

Data centre efficiency is commonly measured using Power Usage Effectiveness (PUE), the ratio of total facility energy to IT equipment energy. A PUE of 1.2–1.4 is considered good, indicating an energy-efficient data centre with relatively low overhead from cooling and power systems. Comparing this to the global average of around 1.54 (per the Uptime Institute Global Data Center Survey 2025)[8] reinforces the need for improved cooling efficiency as AI workloads increase.

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Improving energy efficiency through ceiling design

Align ceiling layouts with airflow strategy

Ceiling systems should be coordinated with the structural grid and cooling concept to support consistent placement of supply diffusers, return air paths and containment interfaces. Predictable ceiling geometry helps establish stable airflow paths and pressure zones, reducing recirculation and cooling inefficiencies.

Coordinate ceilings with containment systems

Hot and cold aisle containment relies on effective separation of supply and exhaust air. Ceiling systems must align with aisle geometry, rack heights and containment enclosures to avoid bypass air paths. Poor ceiling coordination can compromise containment performance and increase cooling energy demand.

Control air leakage through the ceiling plane

As rack power densities increase, ceiling airtightness becomes critical. Specifying sealed ceiling panels, controlled penetrations and coordinated interfaces for lighting, sensors and cable trays helps maintain pressure integrity and reduces conditioned air loss into unconditioned zones.

Design for future cooling technologies

Where higher-density or liquid-based cooling strategies are anticipated, ceiling systems should allow for the integration of supply and return lines, additional services and future penetrations without requiring wholesale replacement. Modular ceiling layouts support incremental upgrades with minimal disruption.

Support monitoring and automation

Ceiling zones increasingly accommodate environmental sensors used to monitor temperature, airflow and pressure. Provision for integrated sensors supports data-driven optimisation of cooling performance and long-term energy efficiency.

A TRUSTED PARTNER FOR DATA CENTRE CEILING DESIGN

Partnering with Network Architectural enables architects to approach ceiling design as an integrated architectural system rather than a secondary finish. The company provides access to a comprehensive range of metal ceiling solutions that balance form, function and long-term performance. From standardised systems to custom configurations, Network Architectural offers the design flexibility required to respond to the spatial intensity, high rack densities, airflow strategies and complex service coordination that define contemporary data centre infrastructure.

Metal ceilings deliver high resistance to impact, humidity and environmental stress while maintaining dimensional stability over extended operational lifespans. Customisable panel formats, perforation patterns, infill materials and finishes allow systems to be engineered around project-specific performance criteria; whether optimising return air pathways, accommodating containment strategies, or integrating lighting, security and fire services within tightly controlled zones. This adaptability also ensures ceiling systems can evolve alongside future upgrades in technology and capacity.

Network Architectural's in-house project support further enhances the design process and delivery of ceiling systems in data centre environments. Early-stage technical input facilitates coordination with structural, mechanical and electrical systems, reducing clashes and improving buildability. Rapid concept development, detailed shop drawings and access to local fabrication streamline procurement and installation, helping to mitigate risk in high-stakes environments. By combining specialist ceiling expertise with a collaborative approach, Network Architectural enables architects to deliver ceiling systems that contribute to operational reliability, energy efficiency and long-term resilience.

Cooling energy is the dominant contributor to total facility energy consumption in AI-focused environments.

References

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