Malaysia’s GREEN DIAMOND

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The glimmering green façade of the Malaysia Energy Commission Headquarters known as the Diamond Building stands in stark contrast to the surrounding brown concrete government buildings. It stands apart in other ways, too: its sustainable design and building energy intensity of 20.6 kBtu/ft²-year mean it uses on average four times less energy than typical Malaysian office buildings. The building is designed to showcase technologies that reduce building energy and water consumption, promote use of sustainable building materials and provide enhanced indoor environmental quality.

The Diamond Building’s construction in Malaysia has exploded since the energy efficiency was a top priority in 2005 when the Energy Commission of Malaysia, Malaysia’s regulatory body for energy policies, standards and safety, embarked on building its own headquarters building in the country’s administrative capital of Putrajaya. However, the project team decided to venture beyond energy efficiency by going green, a relatively new term in Malaysia at the time. The resulting double Platinum-rated building is now a tourist attraction within the global sustainable community and serves as an example for private industry.

This building demonstrates that a Green Building Index Platinum rating (Malaysia’s green building rating system) can be achieved with an additional cost of 6%. As a result, the number of green buildings in Malaysia has exploded since the Diamond Building’s construction in 2010. (More than 50 million ft² [4.6 million m²] has been certified by Green Building Index [GBI] in the past four years.)

Diamond Shape

Climate and the solar path of equatorial Malaysia (3° north) helped shape the building’s diamond design. Solar studies showed that 25° tilting façades would provide self shading on the north and south façades. To maximize daylighting, a central atrium was introduced, and the diamond shape was born.

The diamond symbolizes transparency, value and durability, characteristics that represent the Energy Commission’s role and mission as a regulatory body. The shape also represents an optimal design approach to achieve energy efficiency.

The building includes seven floors above grade and two underground levels for parking. The seventh floor includes a small theater, board room and dining room.

Low-e glazing helps reduce direct solar heat gain for the east and west façades. The glazing’s visual light transmittance (VLT) of more than 0.5 allows for effective natural lighting to the office interior in conjunction with lightshelves. The inverted diamond shape increases the ground space available for landscaping, which helps reduce the heat island effect.

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Air-side system addressing the latent load, air movement and air filtration. Primary chilled water is supplied by a district cooling system (DCS) plant. While the facility is called a gas district cooling plant, in reality the existing plant has more

The design building energy intensity (BEI) was 27 kBtu/ft²·year (85 kWh/m²·year), representing a 65% reduction compared to a typical office building in Malaysia with a BEI of 79 kBtu/ft²·year (249 kWh/m²·year). Energy simulation was performed with IES Virtual Environment software conforming to ASHRAE Standard 140-2004 and Standard 90.1-2007 (Table 1 and 2).

Energy efficiency performance of the building recorded for the period from October 2010 to November 2011 is depicted in Figure 1. The actual BEI of 20.6 kBtu/ft²·year (65 kWh/m²·year) has surpassed the design target to achieve an annual energy savings of more than 70%.

HVAC System

The Diamond Building is designed to provide thermal comfort using the following strategies:

- Floor slab radiant cooling addressing the sensible load of the air-conditioned space; and
- Air-side system addressing the latent load, air movement and air filtration.

Primary chilled water is supplied by a district cooling system (DCS) plant. While the facility is called a gas district cooling plant, in reality the existing plant has more...
electric-driven chillers than gas-fired chillers. The building chilled water plant primarily consists of two heat exchangers, one duty and one standby, each of 4,197 kBtu (1230 kW) capacity.

Two distinct control strategies are used for office operating hours (cooling is provided via air-handling units) and for thermal mass charging mode. During the six to eight hours of thermal mass charging mode, chilled water from the building plant is directed to the concrete slab to achieve a slab temperature of 64.4°F (18°C) to 68°F (20°C) to provide radiant cooling during office hours. The slab-cooled concrete floors act as a cooling rechargeable battery, or thermal mass storage, being charged daily from 10 p.m. to 6 a.m. (during the off-peak tariff period).

**Lighting Systems**

The Diamond Building is designed to be at least 50% daylit, without glare and with minimal heat entry. The energy-efficient artificial lighting system is daylight responsive. The lighting load is 2.5 Btu/ft² (8 W/m²) with an illumination level of 27.9 fc (300 lux) to 37.16 fc (400 lux), conforming to Malaysian Standard 1525-2007, *Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings*.

**Daylight Strategies**

**Façade Daylighting.** Daylight is reflected off the mirror lightshelf and window sill, and cast onto the ceiling, deflecting it deep into the room. This design, along with fixed blinds, help prevent glare.
Atrium Daylighting. The daylight design of the atrium consists of three key design elements:

- An automated blind that regulates light penetration into the atrium;
- Different window sizes for each floor; and
- Reflective aluminum panels.

The automated atrium glazing roller blind consists of 24 individual blinds that can form six configurations depending on the outdoor light levels. The blinds allow 30% of the light through to ensure daylighting for the offices facing the atrium even when the atrium blinds are fully engaged.

Two light sensors on the atrium glazing control the blind operation. The principal control strategy aims to block direct sunlight penetration into the offices and to moderate the light level in the atrium, so it is “just right” throughout the day.

Daylight availability decreases deeper into the atrium. For the upper floors, windows are replaced with white walls (to reflect light deeper down the atrium), while floor-to-ceiling windows are used for the lower floors. Aluminum panels mounted on the fourth and fifth floor of the atrium walls reflect light to the first and second floors.

Skylight. At the lounge area outside the small theater on level seven is a skylight that takes in mostly diffuse light from the southern part of the sky. The skylight brings in sufficient light to illuminate the lounge area, eliminating the need for electric lights during the day.

Lighting System and Control

Daylight Responsive Lighting Control. To maximize daylighting, the artificial lighting system is daylight responsive. Two light sensors are installed on each façade with one additional sensor on the first floor to measure the atrium light level.

A building automation system (BAS) centrally controls electric lights in the daylight zones via light sensors. All work tables have individual task lights, providing flexibility and comfort of individual light control.

Energy-Efficient Electric Lights. General office lighting is ceiling suspended with electronic ballasts and T5 tubes of 104 lumen/W efficacy. Compact fluorescent downlights are used in the common areas and T5 light fittings are used in the garage.

Graywater from the building is recycled in a mini wetland area, reducing potable water demand for irrigation. Microorganisms living on the root of the reed bed cleanse the water before it is released.

INTERNAL COOLING SYSTEM

Floor Slab Cooling
Mechanical Ventilation

Source: Greening Asia – Emerging Principles for Sustainable Architecture

Floor slab radiant cooling and a mechanical air-side system provide conditioning and ventilation. The concrete floors are charged each night, acting as a rechargeable battery as they release cooling throughout the day.
The precooled air is distributed through floor air-handling units except at the ground floor where it is introduced directly into the conditioned space. The ventilation rate complies with ASHRAE Standard 62.1-2007. The primary air-handling unit also is designed for space dehumidification. Demand-control ventilation is regulated by CO₂ sensors. This system is designed to provide good IAQ and energy-efficient operation, which is critical in an equatorial climate where ventilation air is hot and humid throughout the year.

The variable air volume (VAV) system with a default minimum airflow setting also helps maintain good IAQ. Following construction, a pre-occupation air flush out was performed by supplying outdoor air to provide 10 ach for at least 30 minutes for the whole building. A permanent air flush-out system, which also meets fire code requirements for a smoke spill system, is provided.

The dehumidified ventilation system also keeps the air dry to obviate the possibility of condensation on the surface of the chilled floor slab, which is maintained at 64.4°F to 68°F (18°C to 20°C) to be sufficiently above the dew-point temperature of 60.8°F (16°C).

A 12-month post-occupancy comfort survey was carried out to collect occupants’ responses regarding thermal comfort, visual comfort, acoustic comfort, glare comfort and odor problems. Over 80% of the occupants expressed satisfaction. The

**KEY SUSTAINABLE FEATURES**

Water Conservation: Water-efficient fittings save more than 67% of potable water compared to conventional water fittings.

Recycled Materials: Represent 33% of material cost. Recycled contents in dry walls, ceiling boards, carpet and floor finishes.

Daylighting: Facade daylighting, atrium daylighting (automated blinds; different window size on each floor and reflective aluminum panels); and reflected roof light.

Carbon Reduction Strategies: Energy-efficient strategies such as daylighting, radiant floor cooling and efficient artificial lighting reduce CO₂ by 1.673 metric tons per year.

Transportation Mitigation Strategies: Ten percent of parking garage spaces are designated for green/fuel efficient vehicles; bicycle racks; location served by public transportation; and shaded walkways for pedestrians (linking with master development).

Other Major Sustainable Features: Rainwater harvesting; gray water recycling via mini wetland; solar photovoltaic array; atrium stratification control; heat pipes; on-site composting; advanced air filtration; condensate harvesting; thermal mass storage; heat recovery from shower drain; and recycling of test water from fire sprinkler system.

The Diamond Building is designed to create a pleasant, healthy and comfortable working environment for occupants. Low volatile organic compound (VOC) paints (certified under the Carpet and Rug Institute Green Label) are used throughout the building. Likewise, only low VOC carpets (Green Label Plus certified) are used. Ventilation air is provided via a primary air-handling unit located at the roof, which precools the air to 68°F (20°C). Heat pipes are installed for the primary air-handling unit to aid in relative humidity control without energy penalty.
Wastewater Recycling. Wastewater (graywater) is collected and discharged to a mini on-site wetland area that incorporates a reed bed planting system. The graywater irrigates the plants within the wetland via a subsoil soaker hose. Microorganisms living on the root system of the reed bed cleanse the graywater. The wastewater is stored for no more than 24 hours, and any excess is channeled to the town sewage system.

Innovation and Green Features
Rainwater Harvesting. Using rainwater for toilet flushing and irrigation has reduced annual potable water consumption by 35% compared to potable water otherwise used for industry standard water fittings and irrigation as defined by the Green Building Index. Rainwater is collected from the 7,530 ft² (700 m²) catchment area dome and stored in four 2,600 gallon (10,000 L) rooftop tanks.

Water-Efficient Fittings. These reduce potable water use by more than 67% compared to conventional plumbing fittings. These fittings include toilets with dual flush systems; faucet aerators; showerhead aerators; and urinals modified to provide a small amount of water, making them suitable for Muslim use. Muslim practice requires males to use water to clean up after using a restroom. A water flush with limited cleansing water of 0.03 L/s (0.475 gpm) is used.

Table 3: Indoor Air Quality (IAQ) Measurement

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Volatile Organic Compounds (ppb)</th>
<th>CO₂ (ppm)</th>
<th>CO (ppm)</th>
<th>Temp. (°C)</th>
<th>RH (%)</th>
<th>Formaldehyde (HCHO) (ppb)</th>
<th>Particulate Matter (10 µg/m³)</th>
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</thead>
<tbody>
<tr>
<td>Level 2</td>
<td>786</td>
<td>470</td>
<td>0.5</td>
<td>72.9</td>
<td>63</td>
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<tr>
<td>Level 3</td>
<td>809</td>
<td>414</td>
<td>0.4</td>
<td>71.8</td>
<td>65</td>
<td>45</td>
<td>12.5</td>
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<tr>
<td>Level 4</td>
<td>706</td>
<td>455</td>
<td>0.5</td>
<td>72.9</td>
<td>60</td>
<td>50</td>
<td>15.1</td>
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<tr>
<td>Level 5</td>
<td>370</td>
<td>453</td>
<td>0.4</td>
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<td>97</td>
<td>45</td>
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<tr>
<td>Level 6</td>
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<td>59</td>
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<tr>
<td>Level 7</td>
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<td>400</td>
<td>0.3</td>
<td>71.6</td>
<td>65</td>
<td>90</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Source: Greening Asia – Emerging Principles for Sustainable Architecture

*Curtain wall and metal clad wall are insulated, while the brick wall is not insulated.

Only complaint identified a lack of air movement in two stagnant areas, which has since been addressed.

As daylight angles shift throughout the year, the building design still allows for ample internal daylighting via the atrium and self shading on the north and south façades.
energy is now connected to the national utility's grid under the Feed-in Tariff scheme (2012). The panels have generated a monthly average of 20,320 kWh (8,300 kWh) and 341,200 kBtu (100,000 kWh) annually.

**Atrium Stratification Control.** An elevated 137 ft (41.8 m) atrium contains the hot air pocket (about 104°F [40°C]) below the atrium glazing. Only the circulation space on the ground floor level of the atrium is air conditioned.

**Advanced Air Filtration (Electrostatic Precipitator).** This air cleaner ensures good IAQ, especially during the time open burning in Indonesia causes haze.

**On-Site Composting.** Landscaping and food waste is composted, and the end product is used on site for landscaping. This strategy reduces fertilizer costs and recycles resources rather than increasing the waste stream.

**Condensate Water Harvesting.** Especially productive for Malaysia’s year-round humid climate conditions, plans in the near future include using the harvested cool water to provide evaporative cooling around the external walkway paths.

**Operation and Maintenance.** The Diamond Building was the first building in Malaysia to engage the services of a GBI registered commissioning specialist, whose services helped improve building operating efficiency.

**Cost-Effectiveness.** The building’s eco-friendly features cost USD$1 million, representing about 6% of the total construction cost. Savings of almost USD$333,000 annually in operating costs from energy efficiency (USD$817,000) and solar power generation (USD$15,000) result in an estimated payback of 3.5 years despite Malaysia’s subsidized utility rates.

**Environmental Impact.** The operational carbon (CO2) reduction achieved by the Diamond Building (as verified by the GBI Assessor) amounts to 1,673 metric tons per year, which is akin to taking 900 cars off the road (assuming each car travels 7,500 miles/year). This reduction is derived from savings of electricity energy alone and does not include reduction due to water savings, waste discharge, refuse recycling and embodied carbon.

**Conclusion.** The Diamond Building represents a new approach toward climate responsive building design in Malaysia. Energy savings of four times that of typical office buildings demonstrate the environmental and financial benefits of strategies such as climatic design, daylighting and in-slab radiant cooling. Good indoor air quality access to sunlight provides a pleasant working environment. Practices such as on-site composting and greywater recycling reduce demand for resources while also reducing the waste stream.

**LESSONS LEARNED.**

Overcoming Skepticism. Convincing clients to adopt energy-efficient building concepts and emerging technologies in a developing country is often more challenging than the design itself. Stories of failures or unassailable performance, especially within the region, had not helped, although such failures are often traced to such technologies not being “tropicalized” to suit the local climate and environment.

Prior to the Diamond Building’s construction, a government demonstration building adopted slab cooling, which required various modifications for over two years before it could finally achieve acceptable occupant comfort.

Fortunately, two favorable factors convinced the client to pursue sustainable strategies for this project. The developer/contractor is a leading proponent of sustainable construction and had been involved in government funded demonstration projects to showcase energy efficiency. In addition, the MEP engineer successfully implemented emerging technologies in the Malaysia Securities Commission Headquarters, an award winning energy-efficient building built a decade earlier.

**Slab Cooling.** Minor condensation was spotted at the chilled water pipe manifold riser cupboards. With a congested piping manifold, proper pipe insulation is difficult and risk of cold spots on the slab exists due to the looped pipe bottleneck area at the riser. Future designs should consider smaller zones served by each riser, since more risers would allow adequate spacing for proper pipe insulation to mitigate such problems.

The slab cooling strategy involves presetting a fixed charging duration based on the best estimated calculations. To achieve uniformity of slab temperature during chilled water charging and eliminate the risk of overcharging, temperature sensors to control the duration of charging should be installed. These sensors can have set-points to allow for dynamic control of the charging process.

**Air Movement.** Recognizing that air handlers sized to remove only the latent load will provide insufficient air movement for a year-round hot and humid climate application, higher air movement was originally addressed by incorporating fan-assisted VAV units. However, due to the extremely high escalated metal costs (when the project was bid out in 2008–09 at the height of the world metal price crisis), these were replaced with normal VAV units. The redesign uses enlarged ringed ducts to maintain a minimum of 4 ach. Unfortunately, due to space constraints, the compromised ringed ducts did not achieve the desired minimum airflows, resulting in a few “stagnant” areas.

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