Construction Technology Used for New Annex of Tatebayashi System Center

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For data centers, consideration for the environment as well as ensuring functionality, performance and safety have become important themes in recent years. The new annex of the Tatebayashi System Center, located in Gunma Prefecture in Japan, which was planned as a next-generation data center, was built using the latest technology introduced in relation to those themes. From the viewpoint of safety and consideration for the environment relating to construction, this paper presents the recent trends and construction technology used in building the new annex of the Tatebayashi System Center.

1. Introduction

For data centers, which are important facilities that support ICT social infrastructure, 24 hours a day, 7 days a week stable operation is a prerequisite. In addition to ensuring the functionality and performance of facilities for maintaining a stable operation environment in data centers, ensured safety with the focus on business continuity plans (BCP), on top of the conventional security centered on crime and disaster prevention, is called for. Furthermore, society is demanding energy conservation and the reduction of environmental loads from the viewpoint of reducing CO_2 emissions. With this in the background and as a measure against global warming, data centers, which consume large amounts of energy, are attracting attention as a place where such emissions should be reduced. There are strong demands to respond to this requirement not simply as an indirect measure for goals such as improving the corporate image but also as a social responsibility.

Under the circumstances, Fujitsu plans to have the new annex of the Tatebayashi System Center (hereafter "Tatebayashi new annex"), located in Gunma Prefecture in Japan, which has been constructed as a new-generation data center, function as a state-of-the-art data center. In addition to ensuring functionality and performance, the emphasis was on ensuring safety and considering the environment from the initial phase of its planning.

This paper introduces Fujitsu's activities in relation to safety and consideration for the environment from the perspective of planning the construction of the building.

2. Ensuring safety

2.1 Recent trends

Too often the safety of data centers is considered to only include security measures, such as those to prevent unauthorized entry, and measures relating to operation, such as those to prevent the unauthorized access to and unauthorized taking out of data. However, measures for safety from the viewpoint of functionality and performance are essential for facilities that house important ICT devices. Above all, to maintain a 24 hours a day, 7 days a week stable operation environment for ICT devices, it is important to use uninterruptible power supply devices and stable cooling (air conditioning facilities). And the establishment itself that houses these facilities and server racks must also be made safe. Safety of facilities when their construction is being planned includes measures relating to natural disasters such as earthquakes, flood damage and lightning, and measures relating to accidents and human damage such as fire and crime prevention.

The Hanshin-Awaji Earthquake occurred in Japan in 1995 and raised people's awareness about earthquake risk, leading to significant changes in the concept of improving construction technology. The traditional idea was to strengthen the structure of buildings against earthquake shocks and endure the seismic force to avoid damage and the point was to minimize human damage. This concept can be seen as not giving consideration to damage to buildings. Recently, however, measures to avoid the impact of earthquakes have come to be demanded for important facilities and houses, and seismic isolating technologies that prevent earthquake shocks from being transmitted to buildings are attracting attention. They have been adopted in an increasing number of facilities. In Japan alone, as many as 14 major earthquakes with a JMA seismic intensity scale of 6 Lower or above have occurred in the last 10 years (**Table 1**) and the fear of earthquake disasters has increased further. At the same time, buildings that adopted seismic isolating technologies have actually been hit by earthquakes, and this has enabled the performance of such technologies to be verified.

Common measures against flood damage include avoiding building data centers in the vicinity of the sea or rivers (areas at an elevation equal to or only slightly higher than the sea level), making drainage plans on the assumption of the maximum rainfall in the past, and taking steps to ensure the waterproofing performance of structures such as the roof, walls and openings. However, recent abnormal weather has made it difficult to take measures because of unexpected flood damage including river flooding resulting

Table 1
Earthquakes with a JMA seismic intensity scale of 6 Lower or above that have hit Japan and the surrounding areas since 2000.

Date	Epicenter and name of earthquake (JMA seismic intensity scale)	Richter scale magnitude (M)	Human damage
July 1, 2000	Kouzushima Island (6 Lower)	6.5	1 dead
October 6, 2000	Western Tottori (6 Upper)	7.3	182 injured
March 24, 2001	Geiyo (6 Lower)	6.7	2 dead, 288 injured
May 26, 2003	Miyagi-Oki (6 Lower)	7.1	174 injured
July 26, 2003	Northern Miyagi (6 Upper)	6.4	677 injured
September 26, 2003	Tokachi-Oki (6 Lower)	8.0	1 dead, 1 missing, 849 injured
October 23, 2004	Niigata Chuetsu (7)	6.8	68 dead, 4805 injured
March 20, 2005	Fukuoka Seiho-Oki (6 Lower)	7.0	1 dead, 1087 injured
August 16, 2005	Southern Miyagi (6 Lower)	7.2	100 injured
March 25, 2007	Noto Peninsula (6 Upper)	6.9	1 dead, 358 injured
July 16, 2007	Niigata Chuetsu-Oki (6 Upper)	6.8	15 dead, 2345 injured
June 14, 2008	Iwate Nairiku (6 Upper)	7.2	17 dead, 6 missing, 488 injured
July 24, 2008	Iwate Engan Hokubu (6 Upper)	6.8	1 dead, 211 injured
August 11, 2009	Suruga Bay (6 Lower)	6.5	1 dead, 319 injured

Source: based on Major Damaging Earthquakes That Hit Japan and Surrounding Areas[1), 2)] by Japan Meteorological Agency (JMA) from localized torrential rainfall and because the acceptable capacity of drainage systems, which are urban infrastructure, has been exceeded. Accordingly, it is important to give consideration to flood damage hazard maps of the planned sites and locations of rivers to take measures against flood damage for important facilities. Such measures include planning the drainage of the entire site and properly designing the floor levels.

As a measure against lightning, the installation of lightning protection equipment is generally required for buildings with a height of 20 m or more. For data centers, which are important facilities, measures must be taken in view of minimizing the impact of lightning on ICT devices as well as protecting the buildings themselves regardless of their height. In view of the abnormal weather conditions seen in recent years, measures against direct and indirect lightning strikes including measures for the outside walls of buildings are essential for data centers, which are not confined to areas subject to frequent lightning strikes.

Fire prevention measures include those against accidental and intentional fires. The Building Standards Law must be observed when taking measures for buildings. In addition, particularly important rooms must be compartmentalized to minimize any damage by immediately detecting fires. The spread of fires from neighboring buildings must also be taken into account and the outside walls must have sufficient fireproofing performance especially when the planned data center location is adjacent to other buildings.

For crime prevention, data centers generally need to be planned in such as way that the security level gradually increases according to the degree of importance of each area from entering the site to the building and proceeding into different rooms. It is important to restrict and manage entry to different rooms. In planning the construction, only one gateway to the site must be provided in principle and the number of entrances to the building must be minimized to restrict entry to the building, thereby increasing security. The rooms in the building are configured so that the physical security level gradually increases. It is essential to plan buildings with enhanced security by combining such physical planning with the security and monitoring systems for entry and exit management.

In the Tatebayashi new annex, ensuring safety at the stage of planning the construction was a very important theme. The following subsections describe the specific measures for strengthening seismic performance and preventing damage from floods, lightning, fire and crime.

2.2 Technologies used in safety measures for Tatebayashi new annex

1) Strengthening seismic performance

The existing Tatebayashi System Center, which has been built by renovating a plant, is located in a site that is not often subject to earthquakes and with firm ground. The building itself is earthquake-proof and its seismic performance has been enhanced in view of its application as a data center. It has already become common practice to use seismic-isolated buildings for the latest data centers, and the Tatebayashi new annex was planned by assuming a seismic-isolated building would be used. Specifically, a hybrid structure with concrete columns and steel beams, which combines the characteristics of concrete and steel structures, has been adopted. This produces a seismic-isolated building with a structure that allows customer systems to be stably operated even when there is a major earthquake 1.5 times as powerful as the Hanshin-Awaji Earthquake. The design of general seismic-isolated buildings is such that the maximum allowable displacement is around 50 cm in the event of an earthquake. The Tatebayashi new annex was designed to have a maximum allowable displacement of 80 cm in the X- and Y-directions on a horizontal plane to further increase safety during earthquakes. The existing building and the Tatebayashi new annex are linked with a connecting corridor. This means the two buildings may shake in different ways in the event of an earthquake. For that reason, the structure is designed to ensure a similar clearance so that it can absorb the displacement with the connecting part as well. This has given the building a high seismic-isolating performance that makes it unaffected by any shaking of the existing building (**Figure 1**).

The seismic isolator uses a combination of laminated rubber and elastic sliding supports. The laminated rubber has a structure in which the rubber and steel plates are alternately laid on top of each other, which reduces seismic force. The elastic sliding support is designed to absorb earthquake shocks by sliding on the slide plate. These are combined in a balanced way and arranged where the building and ground (artificial ground) come in contact with each other, thereby exerting a high damping effect against strong tremors of large earthquakes (**Figure 2**).

As a device for recording earthquakes, a scriber-type antiseismic section displacement gauge has been installed in addition to a seismometer for recording the horizontal displacements between the ground and the building superstructure as trajectories. The records can be analyzed to evaluate the building's seismic-isolating performance. These measures help us to understand how the building moves and will aid in the design of further earthquake measures for the facilities in the building (**Figure 3**).

Important rooms including the server rooms, power receiving and transformation equipment required for stable operation of the data center, uninterruptible power supplies (UPSs), air conditioners, refrigerators and air conditioner outdoor units are installed in the building.

(a) Connection as seen from the left-hand side

(b) Connection as seen from the right-hand side

Figure 1
Movable directions of connecting corridor connections.

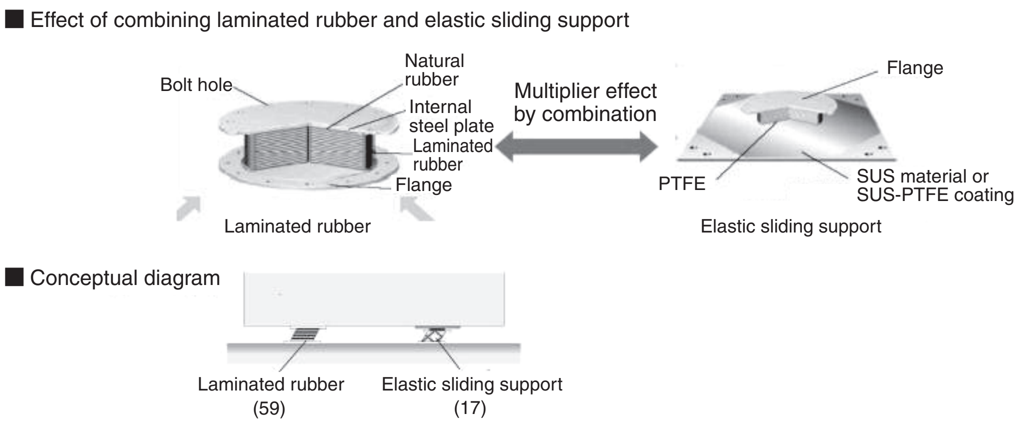


Figure 2
Conceptual diagram of laminated rubber and sliding support.

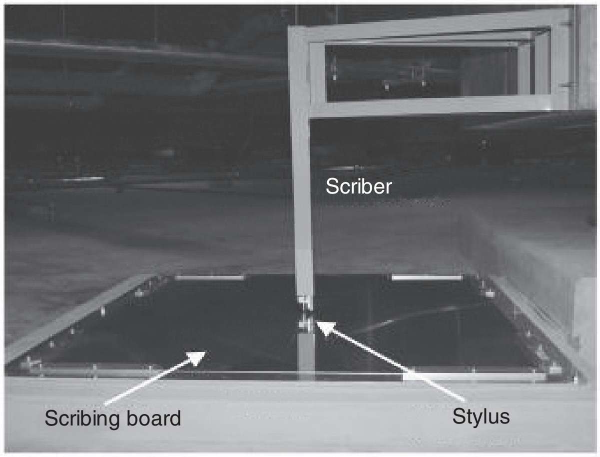


Figure 3
Scriber-type antiseismic section displacement gauge.

The building uses these seismic-isolation technologies and the facility equipment and ICT devices are reliably protected from the danger of earthquakes.

2) Measures against flood damage

Flood damage hazard maps that assume the flooding of rivers in the areas adjacent to the planned site of the Tatebayashi new annex were taken into account. The first floor of the building has been specified to be 3.7 m above the ground to prevent the building from being flooded. In addition, flood protection banks have been built around areas where a special high voltage power receiving unit is installed outdoors or important equipment of the private power generation facilities is installed as a measure against flooding.

To cope with heavy rains, the waterproofing performance of the roof has been ensured and six large-diameter rainwater pipes installed for discharge. This is intended to allow adequate water discharge in the event of rainfall exceeding the greatest rainfall seen in the past due to abnormal weather. For the outer walls, measures against leaks from openings (such as windows) are important and the Tatebayashi new annex has eliminated windows in principle, thereby minimizing the danger of leaks from the outer walls.

In the building, the routes of pipe shafts (PSs) on the individual floors are restricted to minimize the areas in which there is a possibility of water leaks and leakage detectors are installed for prompt detection. In addition, the locations of rooms where water is used and air-conditioning rooms that may cause water leaks are arranged so that they share the same areas on the upper and lower floors. Furthermore, flood protection banks and emergency overflows are provided around the important rooms to prevent flood damage in the case of leaks and in the unlikely event that indoor fire hydrants are used.

3) Measures against lightning

The area in which the Tatebayashi new annex is located is subject to very frequent lightning strikes. For this reason, the grounding performance of the rooftop lightning rods and the materials of the building's outer walls is ensured based on the specification of Protection Level I, the highest level applied to important facilities such as atomic power plants and dangerous facilities such as chemical plants. This has been achieved by using the rolling sphere method (**Figure 4**), a new JIS standard, to take complete measures against lightning. One characteristic of this measure is the use of technology to prevent the devices inside the building from being affected. It has a mechanism in which lightning strikes on any part of the outer walls or the lightning rods installed on the roof are conducted to the ground. The Tatebayashi new annex has a structure with seismic isolators separating the superstructure and the ground. All of these seismic isolators are equipped with grounding so as to promptly conduct current to the ground when lightning strikes.

4) Fire prevention performance

There are existing facilities in the periphery of the building and fire prevention performance is ensured as a building by leaving a sufficient gap from these facilities and using fire-resistant metal panels for the outer walls. The building is

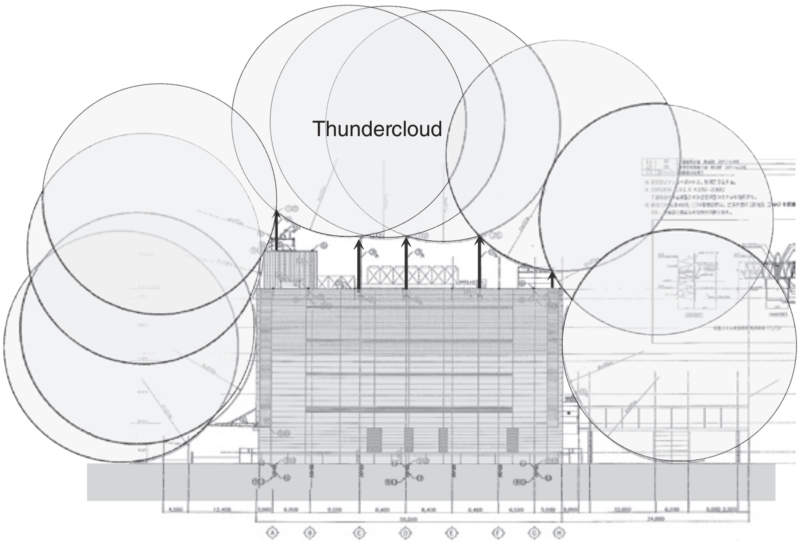


Figure 4
Conceptual diagram of rolling sphere method.

compartmentalized by fireproofing partition walls for each important room to ensure fire prevention performance. Important rooms are also equipped with ultra-sensitive smoke detectors to allow the early detection of fire by predictive detection. For fire-extinguishing equipment, nitrogen gas is used because of its ability to minimize damage to the ICT devices installed in the unlikely event of a fire and because it has a minimum effect on the human body. In addition, using nitrogen helps to prevent global warming since it is a very common substance on the earth.

5) Crime prevention performance

As things now stand, the Tatebayashi new annex is positioned as an addition to the existing center in terms of operation. Fujitsu's plan specifies that people are only allowed to enter the Tatebayashi new annex via the connecting corridor from the existing center, which links the two buildings. The aim of this is to prevent unauthorized entry.

No openings (windows) are provided in the outer walls so that the building has a design that prevents break-ins from outside. In addition, the server rooms are designed not to face the outer wall by providing a buffer zone such as a corridor around them to prevent the direct effect of any destruction of the outer walls.

The building has anterior chambers at the entrances to important rooms from common areas. The server rooms, in particular, have anterior chambers that function to prevent tailgating, and entry and exit are separated to reliably manage entry and exit (see the section on security for details of the security system). The server rooms are unmanned in principle and the flows of operation staff and facility maintenance staff are separated in the plan for improved crime prevention performance.

3. Environmental consideration

3.1 Recent trends

Global warming has become a social issue and the power consumption of the Japanese ICT industry is estimated to increase by up to five times from the 2006 level in 2025 if no measures are taken (Ministry of Economy, Trade and Industry 2006). With this in the background, utilization of ICT is expected to help reduce environmental loads. However, the number of data centers that house ICT devices is estimated to continuously increase by 13% annually and they are regarded as facilities that consume large amounts of electric power. This has led to a demand to reduce the amount of power they consume. As a measure to meet this demand, the focus has been on how to reduce the power consumption because such reduction in data centers will lead to a reduction in CO_2 emissions. Various cooling methods and improvements have been implemented from the point of view that reducing the electrical energy consumed for cooling server rooms (accounting for 44% of the entire power consumed by data centers as shown by some data) in particular is effective.

Because response with cooling methods is especially effective in this way as a scheme to reduce environmental loads, measures including the adoption of high-efficiency devices and efficient air-conditioning methods have been taken at the Tatebayashi new annex. This has reduced environmental loads. While attention tends to be paid to the cooling methods only, measures that involve the building in which the devices are installed are also important. The following subsections describe specific measures taken at the Tatebayashi new annex to reduce environmental loads from an architectural planning perspective.

3.2 Environmental measures of Tatebayashi new annex

Although planning the building of a data center does not have environmental measures as effective as the air-conditioning facility planning, the building contributes to environmental measures as a vessel for maintaining the installation environment of ICT devices and a complement to the air-conditioning facility planning. For the former, improved heat insulation performance is included in the floor and cross-sectional planning as a measure for the server rooms to avoid the effect of heat from the external environment. For the latter, the plan includes using seismic isolation pits as a means of taking in outside air to provide air cooling. This integrates architecture and equipment. As an indirect effect, wall greening has been adopted as a positive approach to controlling the thermal environment of the surroundings and reducing environmental loads through the absorption of CO_2.

Most of the energy consumed by data centers is accounted for by the electricity they use, which means that reducing their electric power consumption allows CO_2 emissions to be reduced. From the viewpoint of electrical equipment, effective measures include energy conservation such as reducing power conversion and transmission losses by means of improving power receiving and transformation equipment and UPSs, as well as energy conservation by reducing unnecessary electric power consumption while equipment is not in operation. From an architectural planning perspective, the generation of electric power from natural energy is considered and energy creation through photovoltaic power generation has been implemented at the Tatebayashi new annex.

1) Improvement of heat insulation performance

To reduce the effect of heat load from the outside of the building to the inside, improving the heat insulation performance of the entire building is important. At the Tatebayashi new annex, outer walls are not provided with openings (windows) but steel panels filled with rock wool that has heat insulating and fireproofing properties are used as the material of the outer walls. The outer walls with their high heat insulating performance have significantly reduced the effect of the outside environment.

In addition, corridors and incidental spaces are provided around the server rooms in an effort to prevent the external walls of the server rooms from coming into contact with the outside air. In this way, the building has a double-shell structure so that it is not directly affected by the heat of the outside air, thereby dramatically improving its heat insulation performance (**Figure 5**).

2) Wall greening

One measure for reducing CO_2 is wall greening. Lava panels, which are used for sound insulation of expressways, have been adopted for the Tatebayashi new annex. Lava panels are a new material developed for greening and reducing CO_2. This has been made possible by a new greening technology characterized by pasting thinly sliced natural lava onto panels with their surfaces sprayed with moss seeds. These lava panels are used for the fence wall of the east gate (front entrance) of the Tatebayashi System Center to control the thermal environment in the surrounding areas and absorb CO_2. The principle of these panels is that water sprinkled on the plants permeates into the lava part from the top of the panels and the water-retaining property of the lava and evaporation of water (evaporation heat) helps prevent the temperature from rising in the surrounding areas. In addition, the moss on the lava surface absorbs CO_2 when it grows, which enhances the effect. Furthermore, the holes in the lava have a noise-absorbing effect (**Figure 6**).

3) Energy conservation

Concerning the power supply devices, high-efficiency UPSs and high-voltage transmission in the building have achieved a dramatic reduction in losses caused by the power supply devices and power transmission. In addition, human sensors

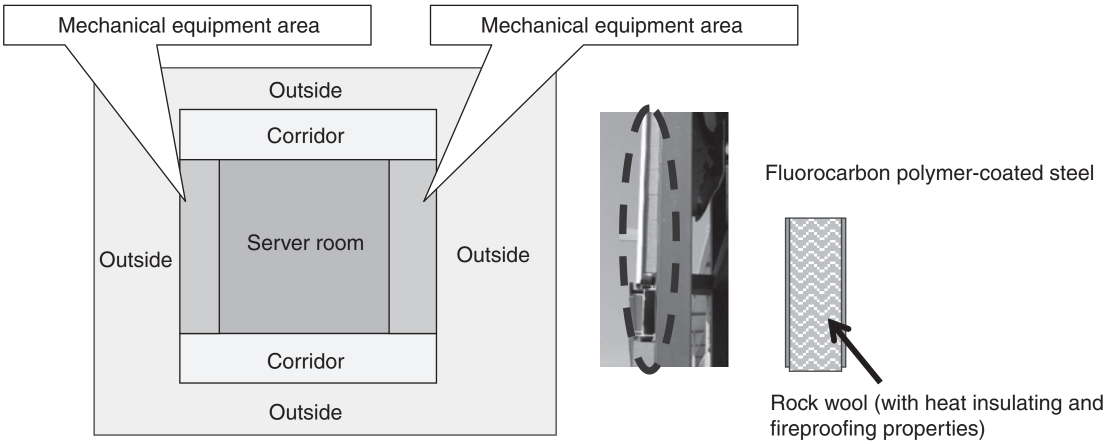
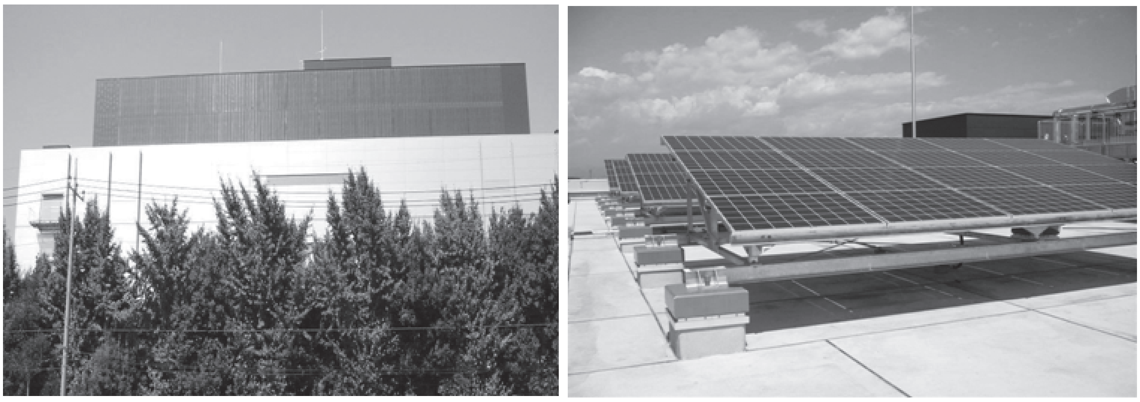


Figure 5
Conceptual diagram of double-hull structure.

(a) Full view of wall greening (b) Planted area (c) Lava panel

Figure 6
Lava panel for wall greening.



(a) Vertical panels (b) Horizontal panels

Figure 7
Photovoltaic power generation facilities.

are used in as many rooms as possible (server rooms, corridors, restrooms, etc.) to control light illumination and extinction. This reduces unnecessary power consumption by lighting while ensuring operability, and has improved energy conservation.

Furthermore, on top of reducing the temperature by introducing outside air via seismic isolation pits (cool pits), which are characteristic of seismic-isolated buildings, and using high-efficiency air conditioners, having an efficient rack layout in the server rooms has improved the cooling efficiency and reduced the amount of cooling energy needed.

4) Energy creation

New photovoltaic power generation panels [**Figure 7 (a)**] integrating sound insulation panels for the rooftop equipment (vertical surface) have been adopted. Together with the horizontally-installed photovoltaic panels [**Figure 7 (b)**], electric power is created by using natural energy to reduce environmental loads.

4. Conclusion

Ensuring functionality, performance and safety is important for data centers. On top of this, we expect consideration for the environment to be in even higher demand in the future. At present, various environmental measures have been devised mainly including improved efficiency of air conditioning in an effort to reduce electric power consumption as a way to reduce CO_2, and the latest technologies that can be adopted have been introduced at the Tatebayashi new annex. In the near future, we expect data centers that avoid CO_2 emissions by making further use of natural energy (photovoltaic power generation, wind power generation, cold energy: outside air, snow and ice, etc.) to appear. Fujitsu has conducted a demonstration experiment (Ministry of Internal Affairs and Communications demonstration experiment 2009)[3] to verify the low-power performance of a data center taking advantage of natural energy (cold outside air, snow and ice). Fujitsu intends to continue to improve environmental measures for data centers by making the most of the various technologies that the entire company has.

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