Responsive Building Elements in architecture

The application of responsive building elements gives new challenges and opportunities for design and architecture
Emerging Environmental Responsive Buildings in Japan

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The meaning of “responsive”; 

1) Responsive to dynamic fluctuation of environment to minimize energy consumption of HVAC and Lighting systems. (technological)
2) Responsive to dynamic fluctuation of environment to maximize human coexistence with nature. (to create more productive and refreshing space) (architectural)
How to Integrate Design, Technology and Renewable energy
Energy Consumption and Evolution of Building

- Conventional High-Energy Building
- Energy Saving with High Efficient Equipments System
- Utilization of Renewable Energy
- Low Energy Design & Better Integration of Technologies
- (GOAL) Zero Energy Building with Responsive Design

Technical solution

Technical solution

architectural solution

Energy Consumption and Evolution of Building
The targets;

1) to minimize energy consumption (low impacts)
2) to maximize human contact to nature (Hi contact)
   (to create more productive and refreshing space)

Therefore, “responsive building” can consist of three patterns;

pattern A : 1)
pattern B : 2)
pattern C : 1)+2).

What kind of “design vocabularies “ and “RBEs” can be integrated for “responsive building”? 
How to respond to the Environment examples

Pattern A

energy efficiency

Pattern B

quality of living space
Pattern A

ZERO Energy House

Hi-efficient HVAC
Super-insulated & Air tight

Clean Energy Use
PV, Fuel gas, etc

Indoor isolated from outdoor?
Pattern B?
Nago City Hall 1983

Office without AC in tropical climate
Responsive but “not comfortable”?
Pattern B?

“Breathing” Hi-rise office
Natural ventilation
Day lighting

Energy efficient?

Kommerts Bank, FRANKFURT 1992
In pattern A, the building may be isolated strictly from the exterior environment because its fluctuation often disturbs the stable, comfortable indoor climate.

In pattern B, the building may impart a fresh and pleasant feeling on occupants but may increase energy consumption in HVAC and lighting systems.

Obviously, pattern C is the most preferable but it is critical to strike a balance between passive-and active approach.
Pattern C

the best combination of active technologies and passive design, where a building can convert its building mode daily and seasonally, corresponding with the exterior environment.
How to integrate?

Pattern A

energy efficient system

Pattern B

Responsive design
Design flow of responsive building

1. Where to be built
2. What to be built
3. Design concept
4. Preliminary design
5. Performance evaluation
6. Final design
7. Operating managing

Climate
Client
IBC

How to integrate?
How to evaluate?

RBEs
Design tool Guide line
Energy related Technologies (RBEs) integrated into Sustainable Building

01. Natural Ventilation / Airflow
02. Photovoltaic
03. Thermal Mass
04. PCM
05. Day lighting
06. Geo Thermal/ Earth Contact
07. Green Roof / Wall
08. High Insulation
09. Water Cooling
10. Rainwater Reservoir
11. Wind Power Generation
12. Eco Material
13. Bio mass
design concept

There exist various design- and technological alternatives for the desired responsive building, even if each results in the same energy consumption or the same environmental impact.

The final decision will be made after extensive discussions among the client, the architect, the engineer and other stakeholders who possess different cultural and scientific background.

It may depend on;

1) Social- and physical environmental conditions of building surroundings
2) Building type and its operating (management) system
3) Lifestyle of the occupants
4) CI (Corporate Identity) or CSR (Corporate Social Responsibility)
5) Private preference or a sense of values of the client
6) Aesthetics
performance evaluation

After the preliminary design is completed, the performance of the building should be inspected.

The two ways to predict and evaluate building performance:

1) use of design tools (simulation tools)
2) use of design guideline

Design optimization persists until the design goals and objectives are met.
Advantages and limits

Today, many kinds of design tools have been developed in determining building performance quantitatively. However the evaluation of total performance can be complex when plural RBEs are integrated into one building, because each design tool is developed to evaluate the building that has a single RBE system.

Using design guideline is a more simplified method, however sometimes too simple to evaluate the custom-made design.
Built Examples in Japan

How were BREs integrated under different design concept?
Example 1
An office building in the suburb

Head office Mabuchi Motor, Matsudo, Chiba 2004
Work spaces are connected by an atrium

3m or more in height of ceiling

No pillar office space of 1500m²
Atrium & natural ventilation

Double glass skin on the outer walls

Partition panel air conditioning system

Thermal storage on the building frame

Cool & heat pit and trench

Roof garden & A proper core layout

A proper core layout plan
**double-skin**

- Brick façade with small windows
- Core zone layout in east and west side
- Atrium
- Office zone
- Office zone
- Roof garden
- Double-skin façade in south and north side
- Thermal buffer zone using perimeter aisle
- = about 40m
seasonal response type double skin

earthquake pit earthquake pit earthquake pit earthquake pit

North side North side North side North side

decrease in solar load decrease in solar load decrease in solar load decrease in solar load

atrium top atriunm top atriunm top atriunm top

diminished heat acquisition diminished heat acquisition diminished heat acquisition diminished heat acquisition

natural ventilation natural ventilation natural ventilation natural ventilation

utilization utilization utilization utilization

summer spring/fall winter
Task air conditioning

- Task zone
- Ambient zone
- Not occupied zone
- Exhaust air

- Task outlet (Manual type)
- Partition (Fixed part)
- Raised floor

- Insulation
- Under floor supply unit
- Under floor supply air chamber

Task outlet:
- 25CMH/person
- 50CMH/person

- Not occupied zone

- Occupied zone
Thermal storage

Return air slits (shows blue line)

Lighting Units

beam

Bottom of the slab
環境調整装置としてのダブルスキン
Example 2
An office building in the suburb

Institute for Global Environmental Strategies, Hayama 2002
Kanagawa, JAPAN
Architect: Nikken Sekkei Ltd
floor area: 6,991m²
structure system: steel frame (SRC frame, RC frame)
completed: 2002
Sun Light Control System at west facing façade, ventilation, air flow window

- **Light shelf:** Takes in reflected light and intercepts direct sunlight.
- **Opaque glass:** Brings low-glare light into the room.
- **Airflow window:** Sunlight heat is removed efficiently at the window to drastically reduce heat radiation from the window surface.
- **Vertical louvers:** Efficiently shield out strong west sunlight. Fabricated from recycled wood.
- **Natural ventilation:** Takes in outdoor air from under the eaves using motorized ceiling fans installed under the floor.
Wind Simulations for Passive Cooling System
Example 3
An office building in the downtown

Takenaka Corporation Tokyo Main Office
Tokyo, JAPAN
Architect: Takenaka Corporation
floor area: 29,747m²
structure system: steel frame (Pillar: CFT structure)
completed: 2004
Concept – Three main requirements –

- Building a high-efficiency high-quality workplace
- Reducing environmental loading
- Pursuing a low-cost solution
Integration of architecture, structure and M&E

Work place

Max. visual communication – Vertical –

Max. visual communication – Horizontal –
Main Measurements of Sustainable architecture

Rooftop gardens
For rooftop greening, Takenaka’s unique thin layer greenery and sedum carpet have been used.

Light well
Along the axis of the building, three light courts, including a stairwell, have been set up to introduce daylight into the interior. Two of them feature a sun-tracking daylight collecting device.

Ice storage
On the rooftop, Takenaka’s proprietary ice thermal storage unit has been mounted. High efficiency equipment has also been used for other heat sources.

Pre-cast concrete panel
For use as the exterior finish material, Takenaka has developed a polished pre-cast concrete panel based on recycled materials.

Flush zipper gasket
Takenaka has developed a new type of thin gasket sash which does away with metal parts and allows the mounting of glass nearly flush with the exterior wall.

Low-emission glass window
Takenaka has improved the thermal characteristics of the building by reducing its thermal load through the adoption of low-emission double glaze windows, as well as the minimization of the overall window area on the exterior wall.

Natural draft
The high-functionality exterior wall introduces natural wind as a breathing skin. After flowing through the interior, the wind leaves the building via light courts set up along its axis.

Hybrid air conditioning using natural wind
The air conditioning system has dramatically reduced energy consumption by combining low-temperature mechanical air conditioning and natural draft.

Low-temperature water storage
Chilled water at 3°C is stored in a tank located at the bottom of the building for use for air conditioning purposes. The facility has also be given an emergency water storage function as part of disaster preparedness measures.

Tree planting
To secure an on-site green environment, tree planting has actively been undertaken.

Rooftop solar heat collection ducts
Solar heat is collected and stored for use as an energy source for heating and ventilation.

Utilization of rainwater
Rainwater is stored in a tank located at the bottom of the building for use for toilet flushing and other purposes.
**Q1: Indoor Environment**

Flexible zone control of thermal, light, acoustic and air environments

- **Hybrid AHU every 300m\(^2\)**
- **VAV every 100m\(^2\)**
- **Natural flow of air**
- **Light well**
- **Office**
- **Smoking rooms**
- **Lighting zoned every 50m\(^2\)**
- **Daylight introduced**
Maximized visual communication
Q2: Quality of Service

Spacious working environment with a ceiling height of 3m or more and structural design eliminating duct penetration through beams.
Q-3: Outdoor environment on-site

External appearance designed to harmonize with the surrounding environment, tree planting and rooftop gardens
Plan & Section Distribution of Illumination During Natural Lighting, June 12:00.
Conclusion

It is a necessary condition to minimize the energy consumption. There are many technical alternative ideas and RBEs to do so. Also, there are many architectural alternative ideas to maximize “responsive” feelings of occupants.

These ideas will be integrated under the specific design concept, case by case. Performance evaluation should be included in the design process.
Itoman City Hall
Okinawa, JAPAN
Architect: Nihon Sekkei Inc
floor area: 15,435m2
structure system: RC frame (PC frame)
completed: 2002

Whole Building Covered with Shading Envelope
PV Installed Shading Device
Envelope System Correspondent to Orientation

PV covers 10% of electricity demand, 20% less AC load by shading, 19% by natural vent.
Hokkaido Northern Regional Building Research Institute
Hokkaido, JAPAN
Architect: Nakahara, Atelier BUNK, Shibataki Inc
floor area: 8,356m²
structure system: steel frame (SRC frame)
completed: 2002

Office Space Faces to South
Section: climate control system in summer
Sunshade cloth of atrium

Inclining sunshade of window
Human-centered design

- 50% reduction in operation energy
- Use of natural energy resources: wind, snow, ice...
- Low maintenance
- Regional production
- Low environmental impacts technology

Design Concepts