Architectual Concept of Sustainable Building in Warsaw

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***Abstract*—**The idea of sustainability is an important part of contemporary architecture. The paper is a description of an architectural concept as a certain trial of incorporating the idea to a small scale office-residential building in Poland. On the example of the building, the paper is aimed at showing complexity of problems related to the creation of sustainable architecture. Another purpose of the paper is to show a design process in which the final sustainable architecture is influenced by external conditions, general sustainable design targets and sustainable strategy. For this reason the paper is constructed to reflect this process. To show the complexity of the problem, the architecture of the building is analysed in a wide context regarding: urban matters, function, utility process, structure and aesthetics. As the result a general systematic model of sustainable architecture has been created.

***Keywords*—**Ecological architecture, sustainable architecture, sustainable building.

I. Introduction

THE idea of sustainability is an important part of contemporary architecture. Problems related to the creation of sustainable architecture, sometimes wrongly narrowed down to "low energy building" concept, go far beyond the energetic issues. They are concerned on environmental targets, but also take into account aesthetics, function, internal microclimate and other aspects which affect human psychophysical state.

The architectural concept represents one of the first holistic approaches to the creation of sustainable architecture of the office-residential buildings in Poland.

The object is situated on the outskirts of Warsaw and designed on two plots (750m2 each) as a semi-detached building. It is conceived as a three storey headquarter for a private investor "Studio budowlane - Unity s.c." constructional office.

The office space (ground floor and 1.floor) will room ca.30 users. The 2. floor is destined for flats to rent. The total usable area amounts to ~660m2 and the internal volume: ~ 2000m3.The project is in conceptual stage at the moment.

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Fig. 1 The building's facade (western elevation)

II. External Conditions

A. Requirements of the Investor

- office and residential functional destination of the building;
- the building should be highly adaptive for functional arrangement changes; it should have a big common internal space which could be divided in two independent parts, if required;
- the investment budget is limited therefore it should be taken into consideration in architectural solutions (e.g. no large glazed facades; a simple but modern form of the building);
- a focus should be on ecological matters; they ought to be visible also in aesthetical sense to create a proecologically-oriented image of the investor as the building owner.

B. Local Spatial and Environmental Conditions

The plot where the building is designed is:

- located at the outskirts of Warsaw where low density building (one family houses mainly) and natural landscape dominate;
- flat, covered with ground and grass mainly;
- elongated along east-west axis and of rectangular shape (area: 2x750sq.m); the entry road is from the west;
- provided with all media (i.e.: water ,electricity, gas etc.);
- fully exposed to the sun (no obstacles like trees, other buildings etc.);
- exposed to the cold winter wind from the north;
- calm without noise sources.

C. Local Law Requirements – Important Issues

- max height of the building – 13m.
- max floor number: 3
- min biologically active surface area of the plot: 30%
- geometry of the roof: flat or inclined by 35-45 degrees

III. Sustainable Design Targets

The main target is to create a sustainable architecture which will be expressed through the following proecological solutions:

- energy saving measures: maximal use of renewable energy sources, decreased heat losses;
- low energy technique application, maximal use of daylight, effective cooling without air conditioning systems;
- human friendly measures: natural internal environment (e.g. thermal-, visual environment), individually regulated microclimate parameters, visual contact with the external green surrounding, flexible internal space, aesthetical merits;
- environmentally friendly measures: integration with the surrounding, green surface area retained as much as possible, reduced greenhouse gases emission.

IV. Sustainable Architecture Strategy

The strategy has been worked out under influence of external conditions (point II) and sustainable design target (point III). It may be grouped in three categories:

- **spatial solutions**: solar windows as a passive solar system, compact volume of the building, thermal and visual zoning of the internal space, flexible open space easily changeable, natural cross ventilation;
- **building materials carefully selected and designed:** local and low-embodied energy materials, thermal bridges removed, big thermal mass materials inside, low "u" elevations, natural materials (incl. greenery), physical properties of window glazing adopted to the orientation of the external wall; reduced glazing area from the shaded side of the building;
- **installations and technical devices like**: solar collectors, PV modules, biomas heater, heat pump, mechanical ventilation with heat recovery, energy efficient artificial lighting;

V. Sustainable Architecture Strategy

The sustainable architecture solutions mentioned in the previous point imply architecture of the building in its broad sense. The architecture may be analysed on the basis of the following features: urban elements, function and utility process, structure and aesthetics.

A. Urban Elements

- Volume

The building is shaped as two cubes connected with each other. The cube is one part of the semi-detached building. The shape like this is compact and thus energy-efficient.

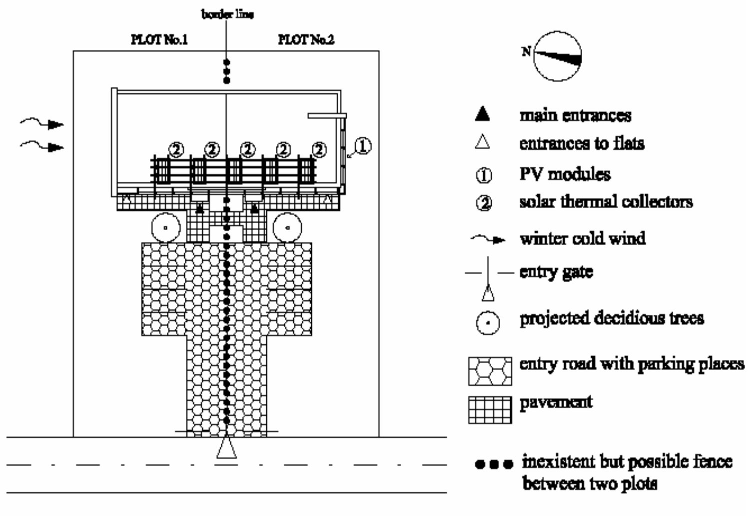

Fig. 2 The building's situation on the plot and the plot's arrangement

- Orientation and spatial elements

The shape of the plot is unfavourably elongated along its east-west axis. This provides the western orientation of the front elevation, which is the longer one. The western side of the building is exposed to the sun and during sunny summer days the internal space is prone to be overheated. Therefore the elevation must be carefully protected against sun. Some deciduous trees will be planted in front of the western elevation to give shadow in summer and let the sun in during winter.

- Position on the plot

The building is positioned on the backside of the plot, so that a sunny foreground has been created on the western side. Such position also ensures that the building will not be shadowed by another object situated on the other side of the street (entry road).

- Surface of the plot

Hard surface area is reduced to the necessary internal entry road, eight parking places and a pavement in front of the building. As a result over 40 % of biologically active surface area has been retained which is at least by 10% more then required by the local law.

B. Function and Utility Process

- Functional arrangement

The groundfloor is a representative entrance with the office zone. On the first floor, there is an office open space. It is accessible for the staff only. The highest floor is designed as residential area divided into two separate flats with their own independent entries from the outside (1 flat per 1 of the 2 parts of the semi-detached building).

However, this arrangement can be easily changed if needed. For example, the first floor may be quickly adopted to another flat or 3-4 flats may be created on the second floor. These changes require only some petty modifications of the partition walls and door openings. In the result, 16 different

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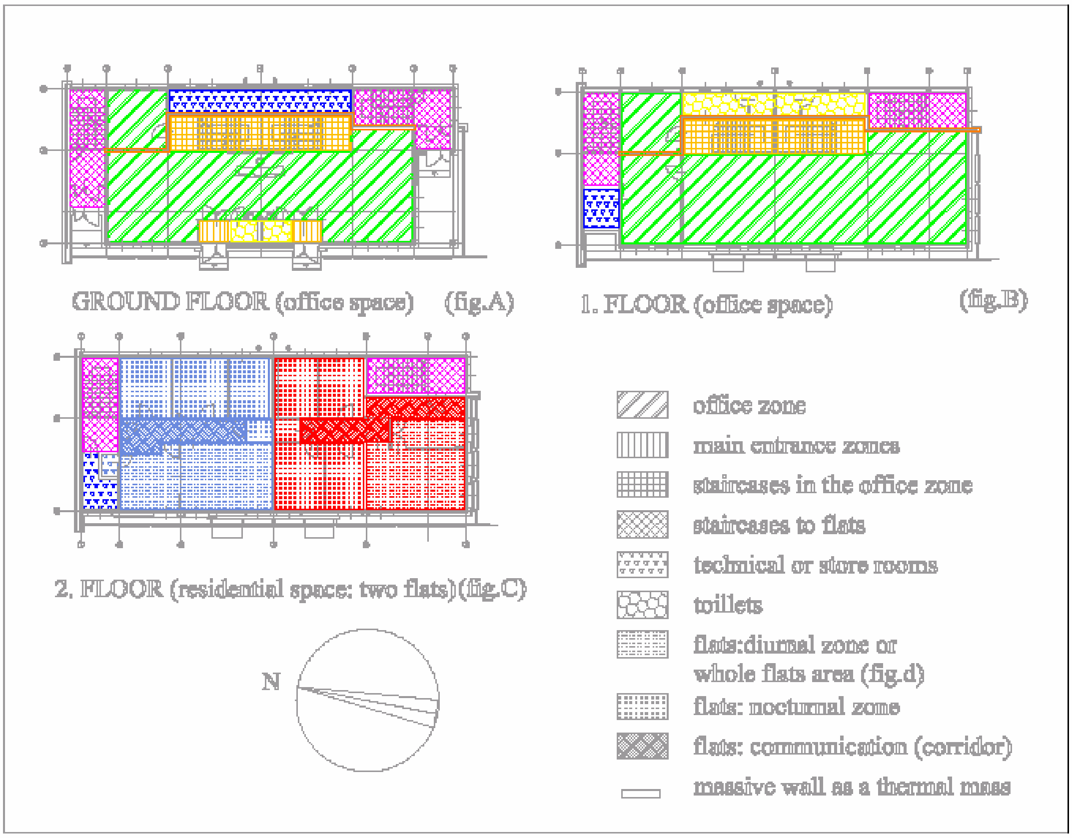

Fig. 3 Layouts - functional arrangement

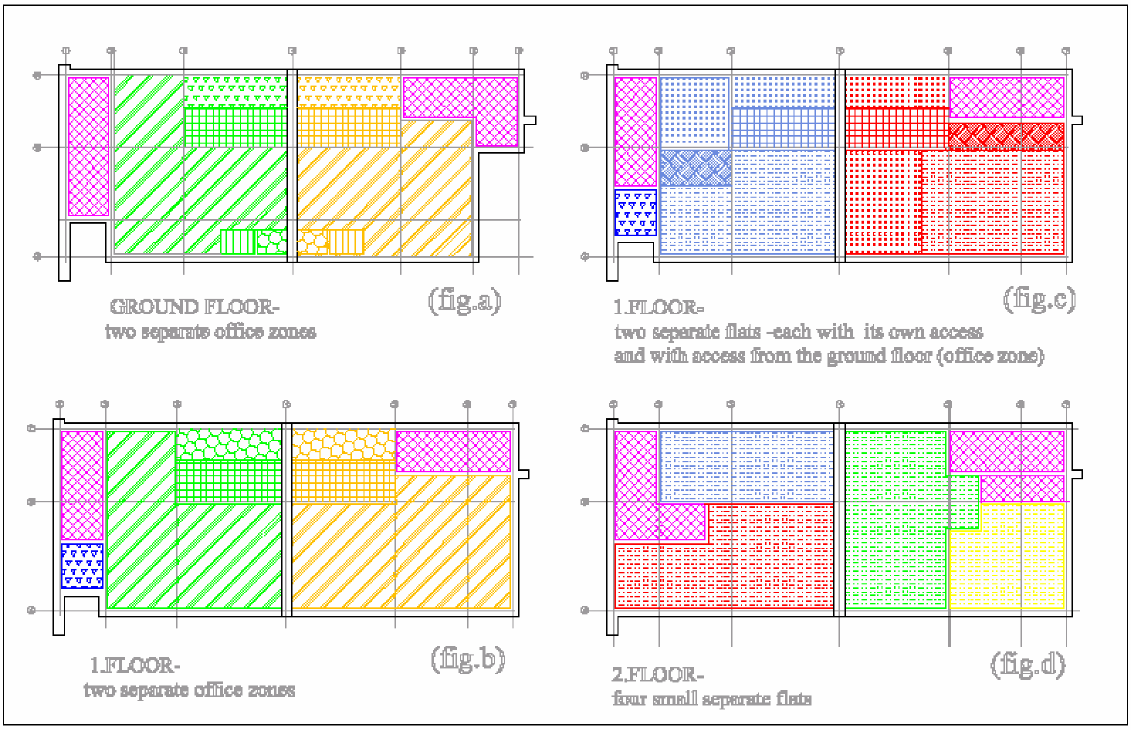

Fig. 4 Some chosen configurations of the functional arrangement showing high adaptability of the building's inner space (description - see: Fig. 3)

configurations of the functional arrangement are possible. The high adaptability of the inner space is regarded as an architectural feature that potentially increases longevity of the building according to the idea of sustainability.

Functional arrangement is the result of thermal and visual zoning concept. The office places situated on the ground and on the 1. floor are placed close to the southern and western windows. This zone provides the best visual and thermal conditions. The office working space is only 6m. deep so that even in central part of the building an efficient level of daylight may be expected. Eastern zone which provides poorer thermal and visual conditions is assigned for temporarily utilized space, like a technical room, toilets and a staircase. There is another staircase in the northern part of the building. This zone acts as a thermal buffer. A massive wall which separates office and temporarily utilized space from each other acts as a thermal mass.

On the 2. floor, the flats are divided into so called diurnal (i.e. kitchen, main room) and nocturnal zones (sleeping rooms). The sunniest areas are assigned for diurnal zone.

- Heating

In cold days the internal space will be heated by biomas heater mainly. Biomas is a prospective renewable energy source in Poland which is relatively cheap and more ecological than traditional energy sources like coal, oil or gas.

For the hot water preparation, the heater is combined with flat plate solar collectors placed on the roof (15m2 of total active surface area) and 800l. water tank. The collectors are south oriented and inclined at the angle of 37 degrees to the horizontal surface. They are designed in five rows. The gaps between them have been calculated in such way that none of them is shaded by another anytime. The collectors are fully exposed to the sun. These solutions are going to guarantee the highest operational efficiency of the collectors. It is assumed that the solar installation will cover the 100% hot water needs in summer and will be supporting the biomas heater through the remaining seasons.

Some heat gains in the inner space are expected through solar windows, especially the southern windows. For this reason their surface area is larger and the glazing parameters are well fitted to the solar gains ("g" coefficient value[1] =80% whilst 60% in the remaining windows with low-e glazing).

- Ventilation and cooling

The office floors are fitted with decentralised mechanical ventilation system with a heat recovery. During winter, the system will provide thermal and hygienic comfort. It will allow to avoid opening the windows which would be unfavourable in terms of energy efficiency of the building.

The system consists of PVC pipes which are combined with air-to-air heat pump. In summer the incoming air will be cooled down to the required temperature by the heat pump. Analogously in winter, the system will be delivering warmed, fresh air from the outside to the interior. Both, in hot and cold days, the "used" warmed air from the inside will be drawn out by the exhaust pipes. In cold seasons the heat from the air will be recovered by the heat recovery device and will support heating circuit of the building this way.

During sunny days, the ventilation system will be supported by photovoltaic (PV) installation. PV modules made of multicrystalline cells have been applied on the most favourable southern elevation. They are inclined at the angle of 30 degrees to the horizontal surface. This inclination is optimal for the solar energy use in summer, when the cooling needs are highest. Anyway, for the economic reasons, the use of PV modules is rather modest. Their total area is only ca.16m2 that stands for ca.2kW of total power. One can estimate that it will give ca.1500 kWh/a of energy and compared to energy generated from coal, reduce CO2 emission by ca.1250kg. per annum.. This small installation is attached to municipal electric grid. The electric current from the sun may be replaced by the electricity from the grid anytime when needed.

PV modules play another role. They have been used as a "shadowvoltaic system" – a kind of external blinds of the southern solar windows. They are designed in rows that does not disturb a view to the outside and let the winter sun in, while protecting against summer solar rays. The wooden lamellas of the western solar windows have been designed the same way however their position is different, as it must have been set to the smaller inclination of western solar rays incoming to the façade.

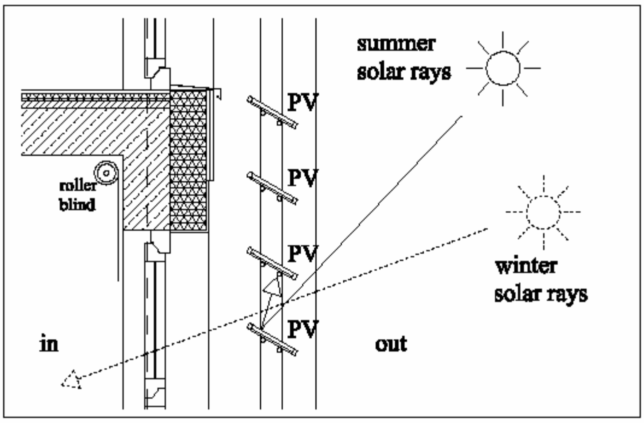

Fig. 5 The section showing the idea of PV modules application as a "shadowvoltaic system"

The building is conceived to use natural ventilation as much as possible. Cross ventilation is possible thanks to openable windows and a small depth of the office open space (esp. in the office zone the ventilation is highly required). A big height of the office rooms (3.15m.) is a factor which facilitates efficient air movement. In the resiential zone, natural stack ventilation will be used.

The windows are divided. The smaller upper part, when opened will serve for a nocturnal cooling. Massive exposed ceilings and a wall as a thermal mass will accumulate the cooling load in their structure thus becoming passive cooling elements.

- Lighting

The lighting system will be fitted with low-temperature, energy efficient fluorescent lamps, individual dimmers and timing switches. In the office zone, a two-component lighting system will be applied. It consists of the low-

[1] total solar energy transmission coefficient

intensive general illumination lamps and the high-intensive individual lighting elements.

The building has been designed to take profit from the natural light as much as possible. The idea of visual zoning is combined with some optimizing elements like e.g. white ceilings which reflect and thus introduce the daylight into central parts of the building or internal, individually-handled roller blinds serving as a glare protection. Each room, except two toilets in the residential zone, has an access to the daylight. Glazing applied in the windows has high light transmittance properties (L_t =75%) Glazed surfaces which are exposed to the sun (west, south) are in decided majority.

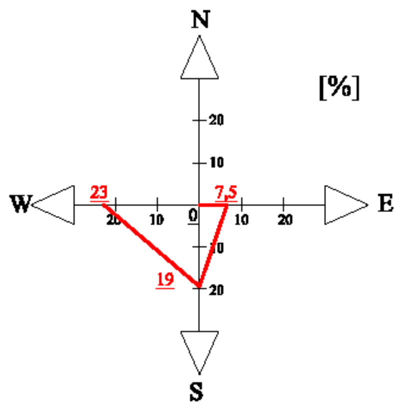

Fig. 6 Participation of glazed surfaces in the whole elevations area according to their orientation

C. Structure and Building Materials

The building is a reinforced concrete frame structure laid on (nx2)x6m.,(nx2)x4m. modular grid. This solution enables creating highly flexible inner space, since there are almost no constructional walls inside. Ceilings are 25cm thick and made from monolith concrete prepared in site. Monolith concrete ceilings, likewise internal concrete massive wall, act as a thermal mass better than other popular building materials (e.g. brick, wood). The external walls are built from 25cm thick gas-concrete blocks. This material has been chosen for two main reasons: it has good thermal properties and a low value of embodied energy. The external walls are covered with 20cm thick mineral wool.

Together with the third outer layer made from pine wood or plaster, the elevations have a very low "u" value which respectively amounts to 0,15 – 0,17 W/m2K. (u<=0,30 according to Polish regulations).

Flat roof of the building is insulated by 25cm thick mineral wool and covered with white gravel (u=0,12W/m2K). Originally it was conceived as a green roof, but due to some technical problems this idea has been abandoned. The white gravel has some advantages thanks to its colour that makes the roof surface reflective. Thus, the gravel will increase solar energy gain to the solar collectors placed on the roof. The roof reflectiveness also reduces temperature level on its surface and in turn protects the second floor against overheating and, in urban scale, prevents negative effect called "thermal island".

There are no thermal bridges. Wooden windows are made of double glazing with argon filling. From the eastern side they have increased insulating properties (u=0,6W/m2K). The "u" coefficient for the southern and western windows amounts to 1,0W/m2K.

External shades in front of the western and southern elevation are supported on a steel structure. The western shades are made of wood. On the southern side (as already mentioned) PV modules have been applied. Eastern elevation is conceived as a wall covered with greenery. The greenery is supposed to be a kind of natural microclimate modifier.

It is assumed that all or at least most of the building materials will be coming from the neighbouring wholesales constructional firms and local manufacturers, so that the transport energy is maximally reduced.

D. Aesthetics

Aesthetical concept refers to "eco-tech" idea, which is a combination of high-tech and traditional solutions. This concept is expressed mainly in elevations where both modern (glass, steel) and natural elements (wood, greenery) are used and put together. The architecture is going to symbolize a profile of the owner, as a modern and quickly developing, but also environmentally conscious, constructional office. Each elevation is different. It reflects a dialog between the building and the environment.

Technical and constructional elements which are the component of energy concept idea (solar collectors, PV modules, external lamellas) have been used as an "aesthetical tool" at the same time. This is clearly visible on the western and southern elevations.

The western elevation, which is a façade of the building, has been proceeded by a steel frame as a support for wooden lamellas. They create rhythms and various divisions on the elevation. Windows are visible in the background. The roof solar collectors have been designed close to the western edge of the roof and slightly lifted over its surface, so that they are visible on the elevation. They are an important aesthetical component which "closes" the building volume from the top. These all solutions enrich the composition of the elevation and are conceived to increase architectural expression of the building.

The southern elevation is fitted with lamella-like PV modules instead of the wooden lamellas of western elevation. Their navy blue and reflective surface together with the exposed steel structure has also been used to strengthen the architectural expression. Unfortunately the building's position on the plot (which is a result of the plot shape) makes the southern elevation a bit hidden. Anyway, one has to mention that PV modules as a "shadowvoltaic

(a)

(b)

Fig. 7 The building seen from the south-west (a) and north-west (b)

system" have been used for the first time in Poland, so the modules may be perceived as an important marketing tool. In contrast to the above described elevations, the northern and eastern elevations are "calmed down". Massive surfaces and natural elements dominate there. The northern elevation, for the energetic reasons, is devoid of any openings. Its homogeneous wooden surface symbolizing the environment is used as a background for the owner's logo.

VI. Conclusion

The experience of the above mentioned design process allows to formulate some remarks and conclusions:

- All external conditions must be taken into consideration to formulate sustainable design strategies; for example – primery idea of undreground heat exchanger application must have been abandoned due to unsatisfactory plot area. The external conditions may also affect architecture directly (for example local law requirements concerning roof geometry influenced the shape of the building);
- Sustainable strategies should be formulated in pre-design stage, as they directly refer to architecture in its wide context (point V);
- There are distinct interactions between the features of architecture described above and sustainable strategies. It means that not only the strategies influence architecture, but also architectural features impose an impact on the strategies in the optimalization process. For example the building orientation (an urban element) required using dense shading devices on the western elevation (which are part of solar windows representing sustainable strategy).
- There are also interactions between the features of architecture themselves. It means that a sustainable strategy influencing directly one feature of architecture makes other features being affected. For example the idea of flexibility and adaptability of the inner space exerts influence on functional arrangement but also indirectly forces a modular structure of the building;
- In conclusion one can create a general systematic model of the sustainable architecture:

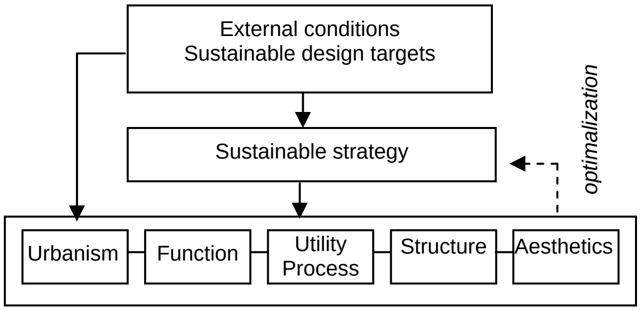

Fig. 8 General systematic model of the sustainable architecture

Besides:

- Sustainable measures may be and in some cases even should be a multifunctional component of architecture. For example, PV modules may be not only an electric current generator, but also a shading device influencing thermal and visual comfort, as well as an aesthetical and "green-image" element;
- Aesthetics is an important and indispensable part of architecture. For this reason all external devices used as a low-energy tool should be reasonably and consciously applied in this context. For example solar collectors with their exposed supporting structure are usually suitable to strengthen architectural expression.

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