Solar Energy in Architecture - Novel Facade Collectors

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Review paper

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The use of solar energy in architecture becomes more and more attractive nowadays. It offers great benefits such as: fossil fuel reduction, less CO₂ emission that labels the architectural goods as eco-buildings. Particularly, the use of solar thermal systems in building integration has a big potential.

Façade solar thermal collectors show double benefits in new architectural goods: integrated functional elements that fit the architectural appearance very well and at the same time they use a high fraction of solar energy for thermal energy needs of the building. This is a sustainable way of use of solar energy and consequently decrease the CO₂ impact to the environment.

In this work, the new model of a façade windows-like collectors and their advantages are described. Namely, it is an ideal module to build-it in the south façade of the building; it could be residential, manufacturing or office building. With facade types of collectors, the architectural appearance of the buildings is not destroyed and at the same time the build-in elements are functional: they participate to a great portion of total energy needs of the building.

Key words: *facade solar thermal collectors, energy-efficiency, building integration, long term stability*

1. ARCHITECTURAL INTEGRATION OF FACADE SOLAR THERMAL COLLECTORS

Concept of energy efficient buildings does not only mean use of insulating materials to build them, but also use the energy from renewable source for the needs of the building. Those buildings are declared as eco-friendly objects.

Nowadays, it is very important that architects and designers should accept a new way of thinking for buildings where beside the architectural appearance, the energy efficiency of building will be also an important and valuable part of their decision. Usually, the architects are mainly focussed on a good appearance of the building; they are less interested in use of free renewable energy options. The most ecological and sustainable energy source in this case could be the use of solar energy that could be used for heating of sanitary water as well as for space heating of the eco-friendly buildings.

Usually, solar thermal collectors were installed on roofs, but not on facades; that philosophy is changed in the last decade or so. The ratio of available roof space and the required solar collector area is usually too small, and consequently it is difficult to supply energy from those collectors for the total energy needs of the building.

In this context, this could be overcome in the following way: if there is enough space on the south facade wall of the building then the solar collectors could be installed there [1 - 4].

Actually, the south facade of the building could be more attractive and better place to accommodate the „functional„ building elements like windows solar thermal modules instead of their installation on the roofs of the buildings.

Another benefit for solar facade collectors is the fact that their appearance could be very similar to the windows (glass) surfaces. They could be mounted in the same windows frames as the regular window glasses.

Due to the fact that facade collectors will be mounted under angle of 90 deg. on the façade wall that means collectors' efficiency will be decreased annu-

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ally (particularly, more in summer time than in winter) due to the fact that Sun has lower position in winter period - (Figure 1). One way to compensate this decrease in collector's efficiency could be the use of collectors with very high efficiency.

Figure 1 - Roof versus facade collector annual yield pattern. [3]

Although, vertical placement of collectors on a building will not maximise the peak yield possible during summer, it makes it easier to scale a system for specific average requirements. As can be seen in Figure 1 - the yield is much more constant in case of façade placement. Hence, overheating or overproduction can be minimised.

In addition, with the right design the shortcomings due to the façade placement can be compensated by reduced thermal losses. In this context, the use of appropriate insulators and designs of the facade collectors could help in decrease of thermal losses.

The insulating options come from the way of mounting of: window module (Figure 2) in the (existing) windows frames or mounting directly to the facade (Figure 3).

Figure 2 - Window module assembled in window frame (insulation behind the window module).

If the window module is mounted in the window frames (Figure 2), then behind the module is insulation that can be also sliding/demounting wall in order to allow in winter time to replace it and the solar module at the same time not only to heat the water in

the absorber, but also to heat up the space behind the collector module. This is especially important if the back side of collector is made from Al plate that once warms up then by convection will heat up the room space as well.

If there is a case of mounting of collectors on the space between windows directly on the wall of the facade, then modules are framed in profiles (Figure 3). Again, behind it is insulation material and they are almost the same as the windows ones. In this case, insulation could be thicker than in the standard thermal collectors and the efficiency of the solar thermal collector increases.

Figure 3 - Window module assembled on the facade wall (behind it is insulation).

2. CHARACTERISTICS OF COLLECTORS

2.1. Newly produced thermal collectors

Flat plate collectors, after their production have:

- metallic surface and all contacts have a good heat transfer;
- Al or Cu sheets with selective coatings also have very good heat transfer from the selective coating towards Cu tubes;
- selective coatings have excellent optical characteristics.

In this way, flat plate collectors achieve a very good coefficient of efficiency after their production. Those characteristics start to decrease over a certain period of time as results of humidity attack, corrosion issues, thermal dilatation during the day or in different time seasons, etc.

2.2. Characteristics of solar thermal collectors during the exploitation time

In general, expected service life of the collectors is ~ 25 years, but degradation - decreasing of efficiency and the esthetical appearance usually starts already after their installation. Namely, it is shown through following:

- decrease of optical properties / decrease of heat transfer from the selective coating to the fluid;

- temperature shocks of collector's results in different thermal expansions of Al sheets and Cu pipes that causes tension (stresses) in their contacts, weakens their function over a time and sometimes even splits up;
- air and humidity between glass and absorber enable corrosion of the absorber;
- destruction of selective coating as a result of classical ways of welding: a) Standard ultrasonic welding due to the fact of removing the part of selective coating is a critical „corrosive,, point (Fig. 4a), or b) laser welding that makes a point melting of Al and Cu that destroys selective coating on those spots (Fig. 4b);
- destroyed sections of the selective coating allow penetration of corrosion reaction such as water, salts, dust, and their migration underneath the coating (because of missing protective layer that could stop their penetration).

Figure 4 - Standard types of absorber welding: a) ultrasonic; b) laser. [Contact points and lines are initiators for corrosion.].

As results of the above mentioned issues, the selective coating can cause decrease of the optical characteristics of the absorber (collector).

3. NOVEL TYPE OF FACADE-WINDOW COLLECTORS / MODULES

3.1. Construction

The window module is made of two glasses and between them is the absorber. Behind the absorber is material that absorbs the humidity in the inner space that could come during the assembling of the collector (Figure 5). [5, 6]

One of the most important characteristic of these modules / collectors is the fact that water vapour condensation is overcome, otherwise it can destruct the facade appearance and architectural design will be unacceptable. Since that there is no humidity issues in the inner area of the collector, it means that no oxida-

tion or corrosion reactions of the absorber and/or Cu tubes could happen.

Figure 5 - Window facade collectors: a) window module, b) different coloured windows modules, c) set of 4 windows modules.

3.2. Welding

The absorber (Fig. 6a) in the novel windows-like thermal collector is welded in a unique and specific way by use of an automatic welding machine (Fig. 6b).

3.3. Advantages

The main advantages of novel type of window facade collector (module) or CS-collector are summarised as:

- a good appearance of modules on the buildings (Figure 5). The CS facade – window collector could be produced in different colours as shown in Figure 5b). The window module could be assembled in window facade frames (Figure 5c).
- the surface area of contact between Cu tubes of the absorber and flat plate (that is Al or Cu material) is bigger than that one of the standard collector; it means that is a better heat transfer between absorber towards absorber's fluid;
- the contact between Cu tubes and absorber's plate is stable and do not changed during aging period of collectors;
- there is no any damage on selective coating; no melting on the selective coating in spots as it happens in other ways of welding like, laser or ultrasound welding;
- there are no waves on Al or Cu absorber plate due to the novelty in absorber's welding (novel CS type of welding).

a)

b)

Figure 6 - Novel Camel Solar (CS) type of absorber: a) front side, b) back side with three welding lines.

4. RESULTS AND DISCUSSION

Novel windows-like solar thermal collectors/modules offer great opportunities to be build-in elements in different types of facades. They offer an opportunity not just to replace solid walls of the facade, but to appear like the window- facade / building. At the same time, they are functional elements that are respon-

sible to cover a part of the total energy needs of the building.

Technically the selective coating is totally undisturbed - there is no diffusion processes of oxygen, hydrogen, no corrosion could happen of the absorbers' plate during the long period of its lifetime. Comparison of efficiencies of the novel thermal collectors and other types of solar flat plate thermal collectors showed greater efficiency for the novel type of collector (Figure 7). The reason is that there is no need of use of a portion of collector's energy to evaporate the humidity from the inner space of the collector (humidity doesn't exist at all).

With the novel type of CS absorber welded with three lines on the back side of absorber (Figure 6b) most of the problems of collectors' aging mentioned in section 2 are overcome. Our observations showed the following preliminary results for this type of facade collectors:

Figure 7 - Comparison of efficiency curves of two types of absorbers: laser welded (blue line) and CS new type of absorber (red line).

Optical characteristics measured in in-house facility are nearly the same over a period of time of 2 years; visually it is not possible to see any destroying of selective coating,

During temperature shocks tests (from -20 °C to +100 °C), it was showed that welding lines stay nearly the same on contact areas and consequently no changes on heat transfer.

Due to the fact that there are no humidity issues between glass and absorber (Figure 8) corrosion on the contacts between Al sheets and Cu tubes is not happening and is not visible.

No destruction of selective coating appeared as well as on protective layer of the coating after the stress tests; therefore the optical characteristics after aging of the absorbers/modules are nearly the same as initial ones.

An independent R&D laboratory performed measurement of efficiency of collectors assembled with laser welded absorber (blue line, Figure 7) and new type of CS-absorber (red line in Figure 7). In

temperature range from 0 to 100 °C, new type of absorber has 7 to 8 % better efficiency compared to the efficiency of laser welding absorber.

Figure 8 - Comparison of standard flat plate collector with humidity / condensation issues (left) and window CS-module without humidity / condensation issues (right).

CS team performed some in-house humidity tests of absorbers welded in three different way. The less corrosive attack on the selective coating is observed on the novel CS-type welded absorber compared to other two type of standard welded absorbers. Also, on the back side on standard ways of absorbers' welding where is direct contact between laser welded spots and ultrasonic welded area was shown corrosion and forming of metal oxides from that process, but on the back side of CS absorber it is not any traces of corrosion. [5 - 9]

5. CONCLUSION

Novel type of windows facade collectors are functional elements in the new building concepts that beside their good architectural appearance they provide a big portion of the total energy needs of the building that comes from renewable solar source. The main characteristics of these collectors are summarised as:

- The collector's/module's appearance is very attractive; it could be very similar to other windows glass surfaces on facades. There is no additional cost for their installation, because the facade collectors could be integrated in the existing windows frames; this is a big benefit of these type of collectors. Figure. 9 presents installation on the south façade on the production plant of CS (Camel Solar) building (Skopje, R. Macedonia).
- A new type of CS-absorber is assembled in the window / module collector. The absorbers are actually, free of welding lines, waves and folds and present good replace to classical windows. This is due to the fact that a new concept of absorbers' welding is conducted (Figure 5, 6).

- The long term stability of these functional architectural elements is solved, no humidity issues exist (Figure 8), no water vapour condensation during the life time of the facade collectors happens. Consequently, collector's efficiency is prolonged and is stable during their lifetime. Actually, this type of absorber shows better efficiency than other types that are welded in classical way (Fig. 7).

Other aging and performance tests for these collectors are in progress.

a)

b)

Figure 9 - Installed window modules in the existing window frames of CS building. a) Left and right windows columns of the building are existing standard glasses; the middle column of windows (circled in red) are CS-modules; b) CS building with installed standard flat plate collectors, vacuum tube collectors on the roof and window modules in the south facade (the middle window column, circled in red ellipse).

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REZIME

SOLARNA ENERGIJA U ARHITEKTURI – NOVI FASADNI KOLEKTORI

Upotreba solarne energije u arhitekturi postaje sve više i više atraktivna u zadnje vreme.

Ona nudi velike prednosti kao: redukcija fosilnih goriva, manje CO2 emisije što omogućava etiketiranje arhitektonskih rešenja kao ECO-zgrade. Upotreba solarnih termalnih sistema integrirane u objektima ima veliki potencijal.

Fasadni solarni termalni kolektori pokazuju dupli benefit u novim arhitektonskim rešenjima u objektima: integrirani funkcionalni elementi koji odgovaraju arhitektonskim izgledom, a u isto vreme koriste veliku frakciju solarne energije potrebnu za zagrevanje objekta. Ovo je samoodržljivi način korišćenja solarne energije, smanjenje CO2 emisije i doprinos smanjenju zagađivanja okoline.

U ovom radu, opisan je novi model fasadnog – prozorskog kolektora i njegove prednosti. Ovo je idealni modul da se ugradi u južnu fasadu objekta, koji može da bude stambeni, poslovni, proizvodni ... Sa fasadnim tipovima solarnih kolektora, arhitektonski izgled objekta se ne narušava, a u isto vreme fasada postaje toplotno funkcionalna: oni daju veliki doprinos u rešavanju totalne potrebe energije objekata.

Ključne reči: *fasadni solarni termalni kolektori, energetska efikasnost, integriranje u objekte, dugoročna stabilnost*