SUN SHIELDS

By

L. GÁBOR

Institute of Building Constructions and Equipment, Technical University, Budapest

(Received: October 15, 1976)

1. Function

Shadow casting, light obstructing (black-out) structures are important factors, typical, often determinant in realizing architectural ideas, hence in defining the building mass, shaping, proportioning, rhythmizing the façades; and decisive for a building design that is constructionally-physically *correct*, sanitarily *skillful*, energetically *clever* and for the dual of investment prime and operation costs *economical*.

The function of structures in systems obturating façade openings (e.g. windows) and their components (e.g. glass) or accessories (e.g. predisposed lamella rows, shutters) for shading and darkening is to protect some spaces, rooms or parts of the building against excessive heating in summer, together with its unfavourable or harmful (health, structural, economical) consequences; thus

— shading, light damping strives to reduce the summer heat load from the radiant solar energy to the degree required (or specified) as a function of the destination, use, technological limitations of the given building or room.

Practically, this function is equivalent to require all the structure obturating, composing and integrating the opening (window, glass wall, special glass, glass structure,[1] lamella, shutter, grid, curtain, etc.)

— to introduce where possible and needed (by an adequate gap or a special glass) the ultra-violet (UV) light of a wavelength 0 to 0.4 μ and representing only about 3% of heat energy;

— to reduce as far and as proportionally as possible (to about 60 to 80%, i.e. without glass discoloration and colour bias) visible light (of about 0.4 to 0.9 μ wavelength containing about 45% of heat energy); and

[1] Understood in this specific case as composed of two or more glass panes of different properties (e.g. outside reflecting, inside normal) separated by a plastic sheet or an air gap, eventually ventilated.

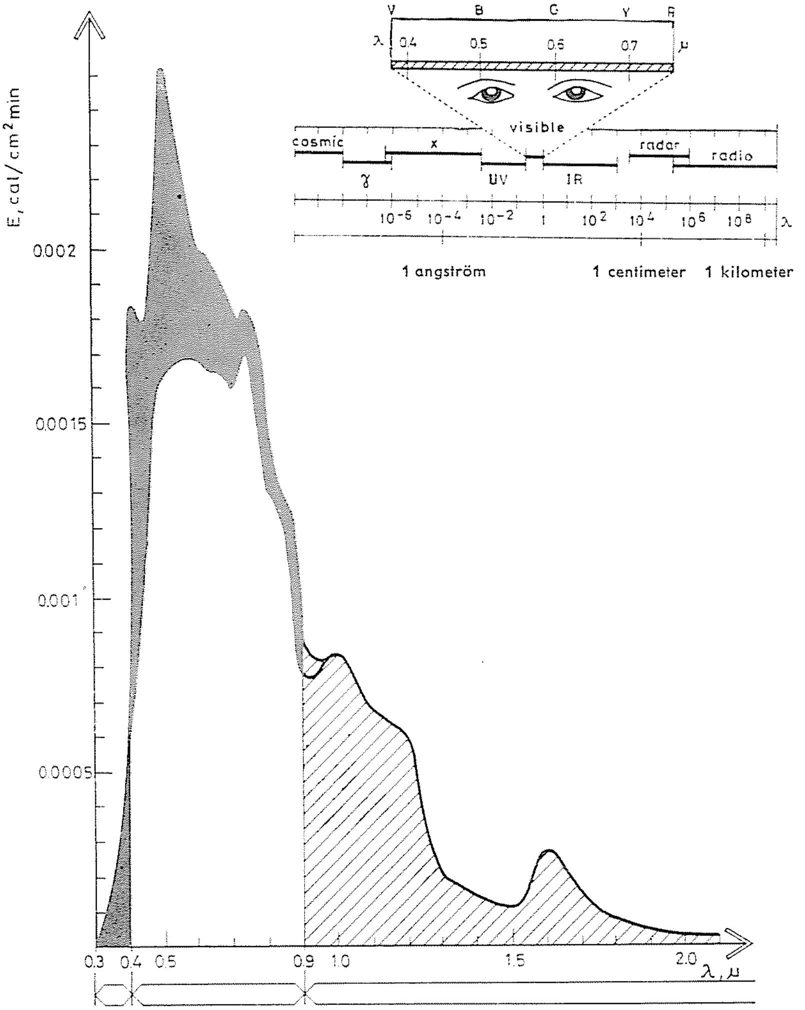

Fig. 1. Distribution of solar radiation energy vs. wavelength

— to absolutely eliminate the bulk of the infrared (IR) rays (longer than 0.9 μ) containing about 52% of energy, causing only heating), (Fig. 1) to prevent development of radiation wave-trap[2] or hot-house effect,

[2] Wave trap phenomenon is based on the Wien law stating that the product of radiant body temperature (measured in K) by the wavelength (in μ) belonging to the emitted energy peak value, $\lambda T \approx 3000$, hence normal glass transmits 80 to 90% of solar energy to the room (all of 0 to 5 μ and some 5 to 8 μ being transmitted and all longer than 8 μ being reflected), thus radiation got in is mostly absorbed by inner surfaces and the wavelength of the reflected part grows to about 20-fold upon contacting inner surfaces at 20 to 30°C, hence it cannot leave in radiation form and adds to heating.

by both correctly selecting and developing its materials, location, design and operation, at an adequate effectivity in terms of the so-called solar factor.[3]

2. General principles of architectural, structural design

Shading and light obstructing structures (systems) have to be designed on the basis of the settlement geography (taking in this country the mid-point values of 47° latitude and 19° longitude, Fig. 2) and surroundings;

— taking the architectural conception (building mass, height, structural system, façade, vitreous ratio, etc.) into consideration;
— enforcing a correct approach to construction physics with due consideration of power economy;
— weighting, ponderating and co-ordinating different, often controversial requirements;
— selecting arrangement, type, material(s), shape, design, mode of building in or operating, surfacing and/or colour.

Thus, an architecturally correct solution of shading and light shut-out is that where

— architectural and structural design is based on the demand of orientation and insolation complying with destination and use of the building, hence on seasonal and even daily duration of admitting or shutting out the sunshine,

  knowing that in this country, shadow casting and light shut-out are only justified in the period from April 17 to June 21 to August 28, and only if the sun is higher than 40° above the horizon ($h > 40°$), the absolutely needed minimum sunshine admittance being determined by the apparent solar orbit curves of February 9 and November 4 (Figs 3 and 4);

— influencing factors are solar damping by the natural and artificial (built) environment determined by the skyline [4] (Fig. 5) that can be altered if

[3] Solar factor N is a positive number between 0 and 1, ratio of total heat energy got in through any window and accessories by any means to heat energy transmitted anyhow — not only by radiation — by a glass pane 3 mm thick.

The N value of a light obstruction is constant, practically independent of orientation and numerically determinable (the window being entirely covered by the light obstructing structure), while for a shading structure covering the window in varying proportions, it can only be determined with a validity for a given type, given orientation and daytime (with continuously varying shielding).

N varies with type, orientation and daytime.

[4] From a sighting point in a plane unbuilt ground, the skyvault appears as a hemispheric surface a part of which is covered by all terrain reliefs, buildings, plants seen from this sighting point, even by the tested building, their continuous skyline outlines the visible part of the skyvault, indirectly determining the insolation degree depending on the orientation, on the season, and on the position of the covered surface part on the hemisphere surface.

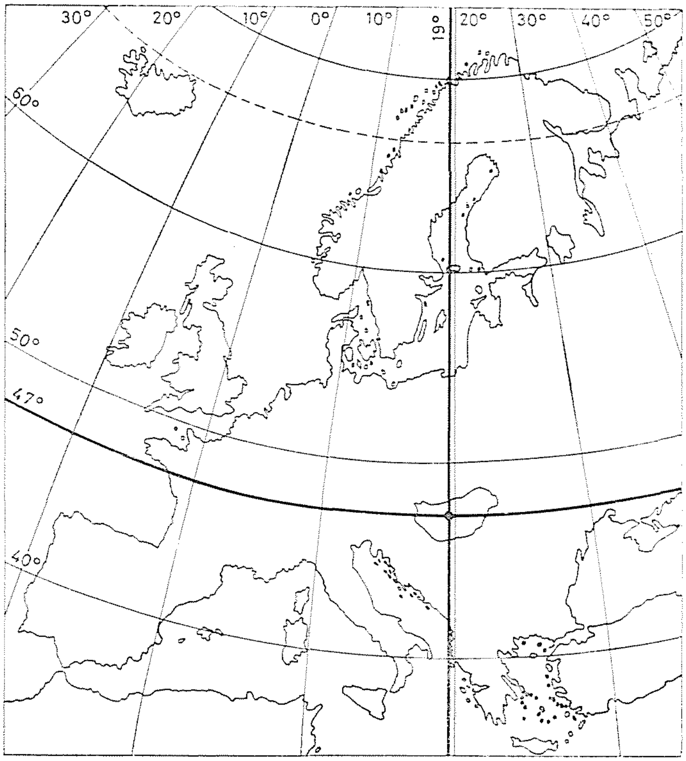

Fig. 2. Hungarian territory centered on longitude of 19° and latitude of 47°

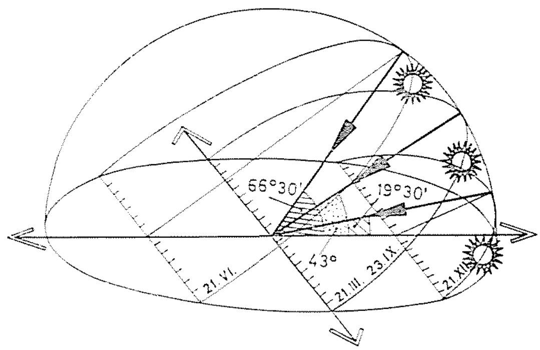

Fig. 3. Solar altitudes H° at noon over the horizon plane, latitude 47°, on June 21st (66° 30′), March 21st and September 23rd (43°) and December 21st (19° 30′

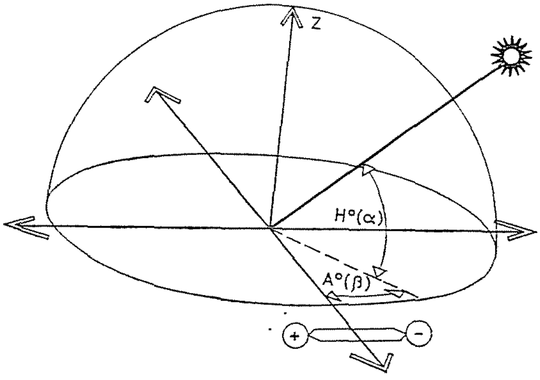

Fig. 4. Position of the sun referred to the direction of south (azimuth A°)

needed by shading or insolation aspects, by implantations, by grouping the buildings or by architectural means (façade design),

being aware that sunshine incident in the strip 0—10° above the horizon plane is negligible because of environmental cover and of crossing a dense layer of dust and vapour, and so is sunshine

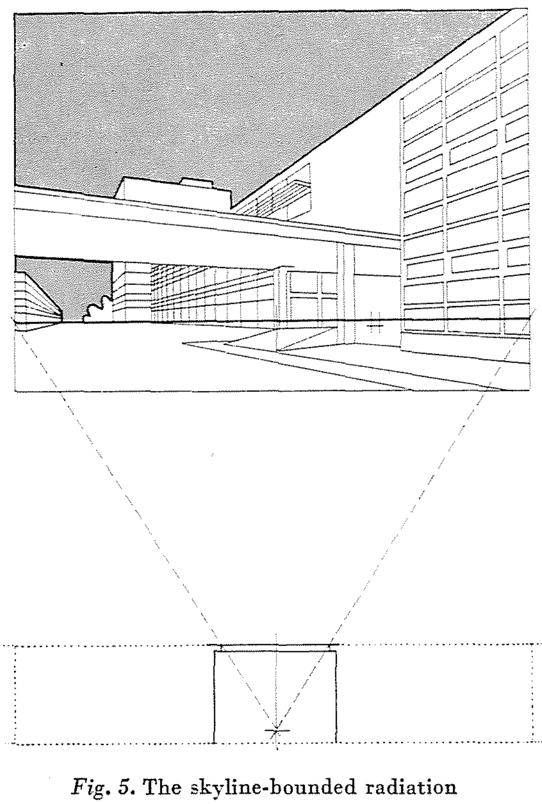

Fig. 5. The skyline-bounded radiation

affecting the façade under the very flat angle of 0 to 10° (of a slight energy content, Fig. 6);

provided these structures are really applied where and how it is the best; and — last but not least —

— arrangement, shape, rhythm, colour, etc. of shades suit architectural conception, mode of expression, design logics — irrespective of insolation differences on different façades — without impairing unity of aspect and character.

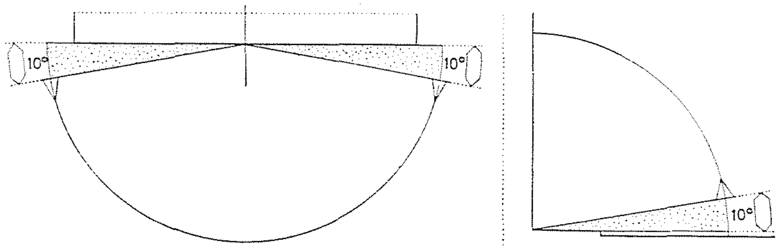

Fig. 6. Negligible radiation range (0° to 10°)

Requirements of construction physics are met by shading and light obstructing structures of a material and design such as

— to transmit as low a percentage of solar energy in the 0 to 2 μ wavelength range, responsible for direct heating, as possible;
— of a surfacing and colour such as to reflect as high a percentage as possible entering in no way in heating; and
— to absorb as low a percentage as possible, this percentage being responsible for heating the structure, kept low by design;
— likely to transmit much of the absorbed energy to the outside (depending on the outer surfacing material and on the reciprocal of the atmospheric moisture, namely high atmospheric moisture causes a hot-house effect in terrestrial environment), a percentage that must not penetrate into the room to be protected;
— likely to emit little heat to the inside (depending on the material and temperature of the inner surfacing material and temperature, advocating the use of a coating or paint that radiates little or no heat to the inside), a heat added to the transmitted energy would cause excess cooling load (Fig. 7);
— likely to give off much heat to the outside by convection (inversely depending on the air temperature, and directly on the aeration possibility and efficiency of the structure), a percentage causing no heating;
— a shading structure of a high specific thermal capacity (product $\varrho \cdot c$) keeping low the proportion of heating due to the absorbed percentage

(a high $\varrho \cdot c$ in the relationship $\Delta q = \varrho \cdot c \cdot \Delta t$ keeps Δt low, and vice versa), peak load (due to increased thermal inertia) being then retained and damped (sum peak being lower than sum of peaks), or, concisely;

— difference between the absorbed heat and the heat emitted to the environment in various manners is kept as low as possible (Fig. 7);

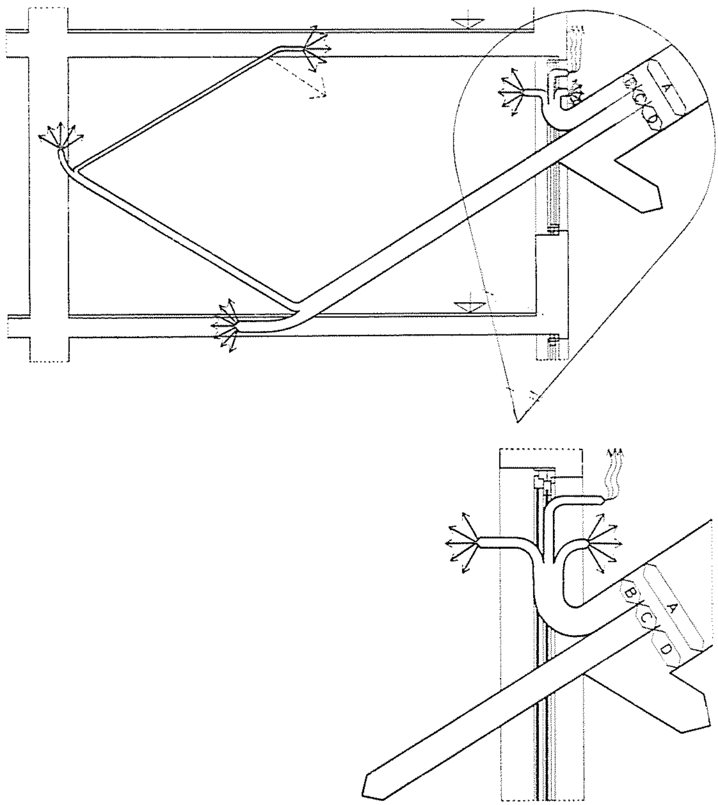

Fig. 7. Energy balance of solar radiation, taking fractions transmitted, reflected, absorbed by the glass, long-wave fractions of absorbed light radiated and transmitted inwards and outwards into consideration

— evaluation of the structure (complex) from the aspects of shading and light shut-out — in view of inherent contradictions and adverse effects — has to be based on the utilization, orientation, environment, etc. of the given buildings, taking into consideration

— that protection against the excessive solar heating of the building is only needed through about 1200 hours from the total of 8760 hours of the year (based on great many years of observations), while during the

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Év
0–1													
1–2													
2–3													
3–4									700				
4–5				–	13	29	19	2					63
5–6			1	29	150	220	184	63	10				657
6–7		1	36	211	468	568	541	339	151	22	0		2337
7–8	4	25	203	508	810	891	892	706	446	161	23	3	4672
8–9	49	133	450	817	1108	1179	1207	1035	754	383	101	38	7254
9–10	159	306	709	1078	1363	1421	1453	1305	1025	622	216	123	9780
10–11	278	468	919	1257	1577	1561	1617	1475	1210	796	315	214	11627
11–12	360	578	1037	1343	1565	1613	1695	1560	1303	889	379	273	12595
12–13	396	620	1063	1321	1529	1593	1705	1568	1298	907	385	286	12671
13–14	368	583	1014	1241	1427	1499	1631	1491	1211	831	333	252	11881
14–15	274	472	854	1063	1250	1334	1443	1321	1023	637	237	172	10080
15–16	148	307	620	831	1009	1127	1202	1063	754	395	121	80	7657
16–17	31	122	354	561	748	859	925	749	450	158	27	11	4995
17–18		13	112	285	465	556	594	426	169	24	1		2645
18–19			6	63	183	267	267	130	21	1			938
19–20				1	26	67	56	9	1100				159
20–21													–
21–22													–
22–23													–
23–24													–
	2067	3628	7378	10509	13631	14784	15431	13247	9825	5826	2138	1452	100011

Fig. 8. Analysis of solar and sky radiation from the aspect of shielding needs. Monthly averages of full sunshine and sky radiation hours (gcal/sq. cm) in Budapest (data recorded by the Hungarian Institute of Meteorology, 1936 to 1960) — for a value lower than 700, no shading is needed; — for 700 to 1100, shading may be useful; — for a value over 1100 (or even 1200), shading is indispensable. Both latter items are indicated in the figure

remaining time (of about 720 to 1200 hours of excessive winter cooling and about 6360 to 6840 hours of so-called transit season) utilization of (rather than shutting out) the natural energy sources would be desirable (Fig. 8);

— that, in addition to bar out overheating, shading and light damping also darken the room (reduce natural illumination), be it some light obstructing system as a shutter, a shading structure (e.g. lamellae) or a special heat absorbing or reflecting glass, likely to impose artificial lighting

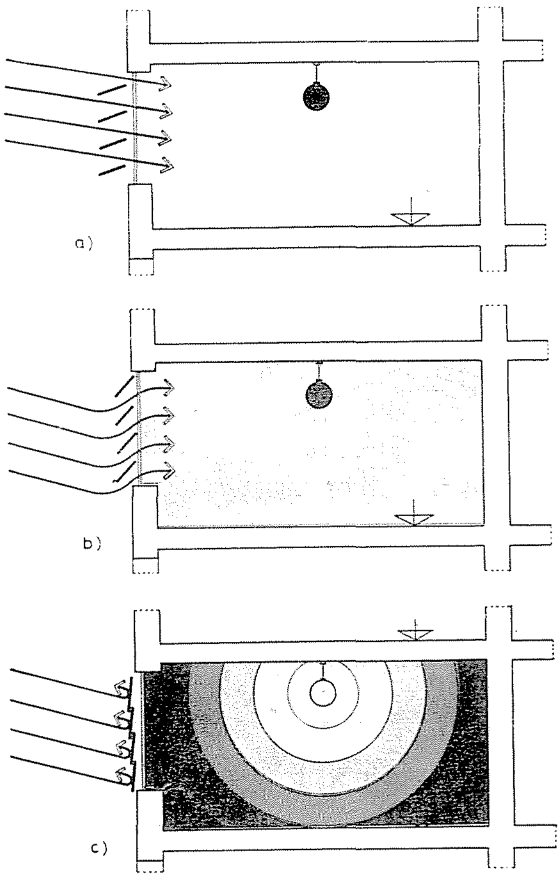

Fig. 9. Darkening effects of shading and light damping: a) full valued light; b) damped light; c) need of artificial illumination

in the room (hence energy wasting) even at the time of outer brightness to provide the light intensity required by the room occupancy (Fig. 9);
— that thermal motion of heat absorbing glasses causes structural difficulties, and their heat absorption causes them to act as radiators and to impair comfort conditions (especially near windows, Fig. 10);
— that shading and light damping structures permitting not to be moved, adjusted, oriented (hence fixed lamellae, screens, special glasses) controlling or shutting out sunshine also in winter and in transit seasons, add to heating and lighting expenditures (imposing the principle of striving to structures of low solar factor in summer and high solar factor in winter, Fig. 11).

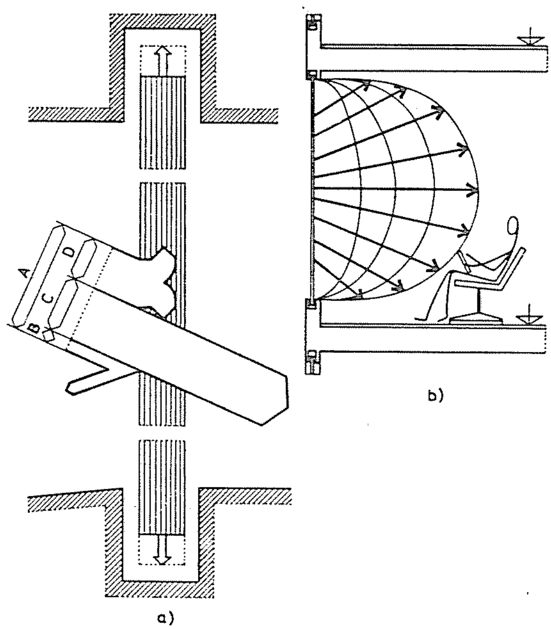

Fig. 10. Structural and comfort aspects of heat-absorbing glass

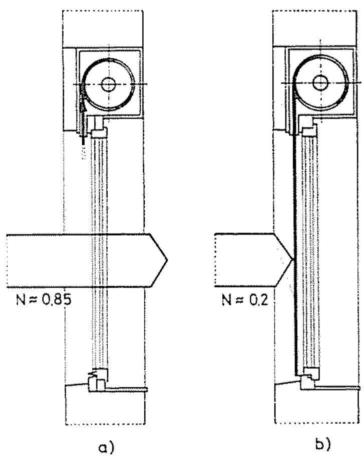

Fig. 11. Example of a structure of low solar factor in summer and high in winter

In conclusion, design for shading and light obstructing structures are only meaningful and economical if

— they meet the outlined, duly co-ordinated variety of demands, aspects, after a due consideration in adequate logical order, in a proportion reflecting their relative importance.

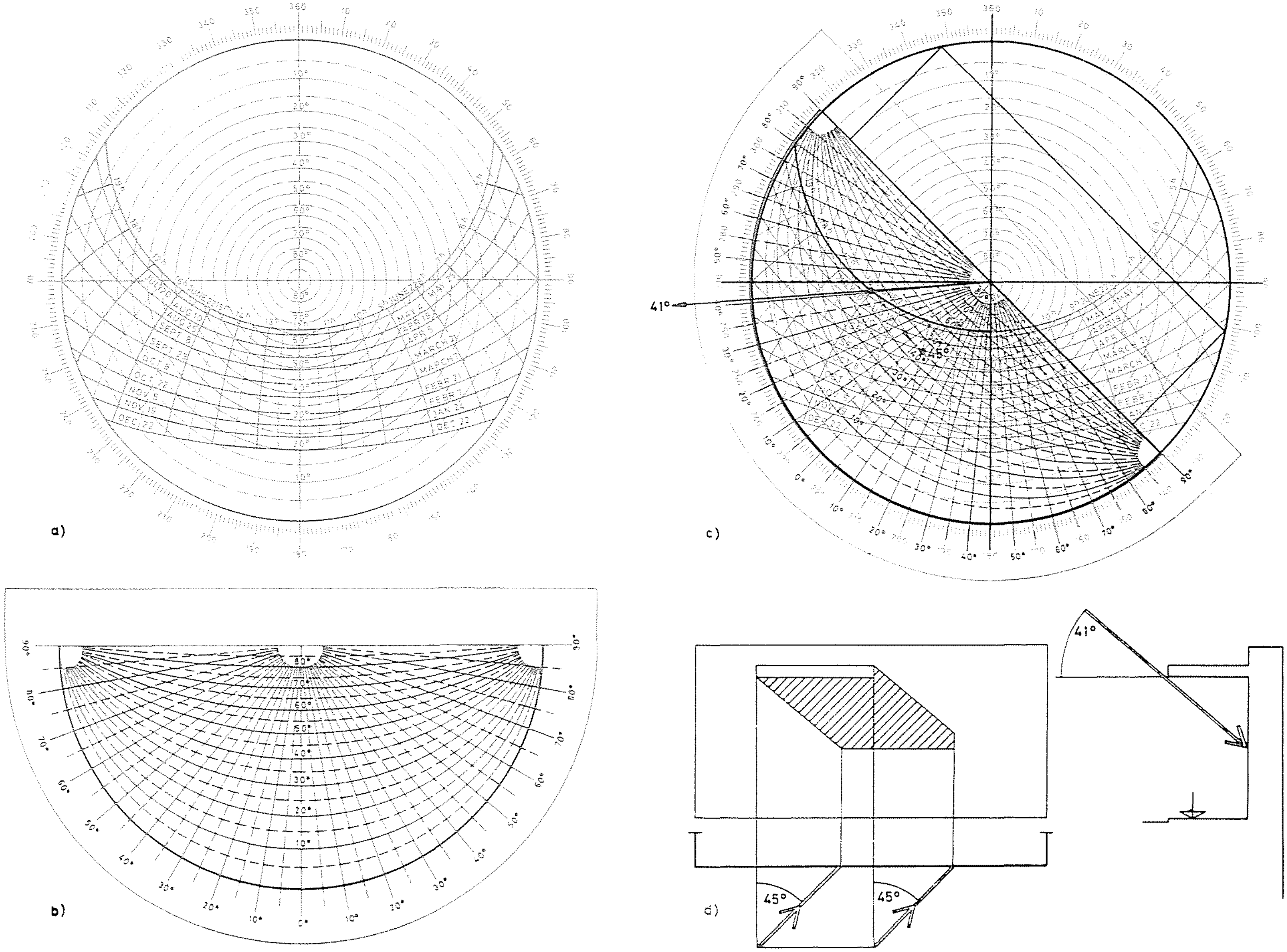

Fig. 12. Use of shadow goniometer for constructing horizontal and vertical shadow angles. a) solar orbit diagram; b) shadow goniometer; c) mode of construction; d) horizontal and vertical shadow angles

3. Procedure and method of design, structural design

The set of operations involved in the design of shading (light damping) complexes or structures of a building of given utilization, orientation, structural and façade system

— starts with determining the design values of insolation and shading times (from. . .to);
— continues by constructing the involved (daily and hourly) critical radiation directions determining arrangement, size and design of the shading (light damping) structure, and the relevant, so-called vertical and horizontal shadow angles[5] (making use of construction aids and indicating geography data and tools) so-called isochronous curves (Fig. 12), etc.;
— and ends by selecting type and location of the structure appropriate for the given case (what, where and how).

To select a given structure, one has to be aware of the wide range of material and structure possibilities of shading and light obstructing structures as concerns either

— architectural aspect and effect (depending on spatial arrangement, material, form and colour);
— efficiency (depending on location and design);
— structural design (depending on the need and degree of motion);
— structural material (depending on the location and operation);
— mode of installation (depending on mounting and connection), or
— economic efficiency (as a combined result of all the above).

Shading and light damping structures are quite different by architectural aspect, character and function — especially depending on their emplacement, namely

— mounted outside, before the window (in particular lamellae, grids) they are decisive factors of division, shaping, outlining the façade, creating shadow effects, often adapted to the kind of landscape or climate, while shades inserted between or as window glass panes (laths or lamellae, curtains or canvasses) little affect the architectural effect (at most by colour or outlines), finally, shades applied internally (behind the window, generally some fabric applied curtain-like) are unimportant, even negligible as architectural features (though affecting the division and operation of the window, hence indirectly its efficiency).

[5] Vertical shadow angle is the projection of the solar altitude on a plane normal to the tested façade, horizontal shadow angle being included between the planes of the solar altitude and of the façade.

Shading, light obstructing structures much differ in efficiency, let alone by the emplacement,

— the optimum being before the glass plane (with a solar factor below 0.2),
— those between window panes are medium (with solar factors of 0.2 to 0.3 as a rule), and finally,
— those behind the glass panes are the poorest (with solar factors of 0.4 or higher);

but also the structural design is of importance, since obviously

— efficiencies of shading structures are rather different between those immobile (both as a whole and in parts, e.g. fixed grids), those partly mobile (with some elements to be rotated and thinned, e.g. Venetian blinds), those entirely mobile (by rolling, staying out, pushing, pulling high, rotating, e.g. shutters, sliding shuttering, adjustable lamellae) of some appropriate material (wood, metal, ceramic, concrete, glass, etc.) and so are costs;
— utilization values of transparent, translucide and opaque structures (e.g. glass, curtain and board, resp.) are rather different, especially in view of the possibilities of — eventually simultaneous — natural light and aeration;
— and so are those built in horizontally, vertically or maybe skew, with a wide air gap from the façade or directly contacting the façade.

Shading and light obstructing structures much differ by sophistication, ease of operation and of cleaning, and — last but not least — by costs.

4. Accessory shading and light damping types

4.1. External shadings

4.11. Nearly horizontal shadings (normal to the façade plane, Fig. 13)

i) *Solid boards.* Penthouse-like r.c. structures, generally mildly sloping outwards, with a ventilation air gap along the façade joint. They are efficient for south (SE or SW) orientations.

ii) *Fixed lamellae.* Aligned metal, wooden or r.c. sections designed for constant ventilation and self-cleaning.

They are advisable and efficient for south (SE and SW) orientations.

4.12. About vertical structures (parallel to the façade plane, Figs 14 to 17)

i) *Solid fix boards.* Metal, r.c., sometimes special glass shading structures mounted on cantilevers much before the façade plane to permit continuous

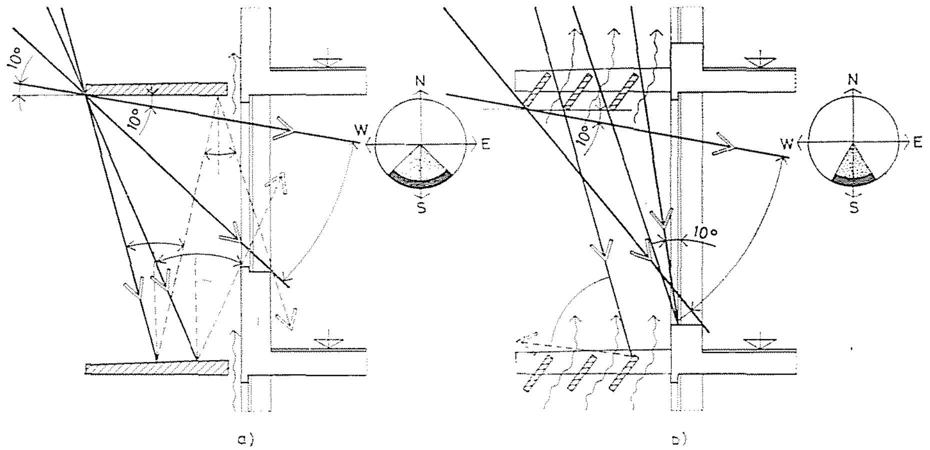

Fig. 13. Examples for outer, horizontal shading devices, normal to the façade plane: a) solid board; b) fixed row of lamellae

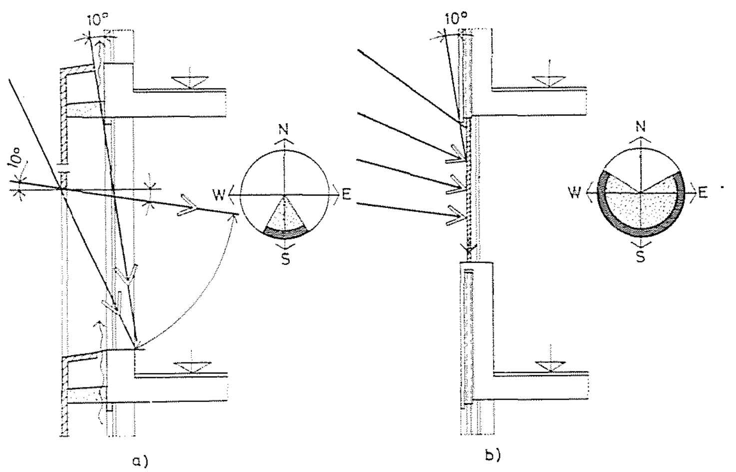

Fig. 14. Examples of outer, vertical shadow casting and light damping devices parallel to the façade plane: a) solid, fix board; b) solid, mobile board

aeration and self-cleaning. They are justified especially in case of south (SSE or SSW) orientations (Fig. 14a).

ii) *Solid mobile boards.* Light damping structures, normally of wood, sometimes of metal, to be pushed (horizontally or vertically) slotted or flaky before the window intermediating a narrow air gap. They shield against sunshine in any direction (Fig. 14b).

iii) *Horizontal lamellae in vertical plane.* Fixed (r.c., metal or wooden) or mobile (mostly wooden) shades designed for aeration. Fixed types are efficient on façades facing east or west, while mobile types suit also SE and SW orientations (Fig. 15a).

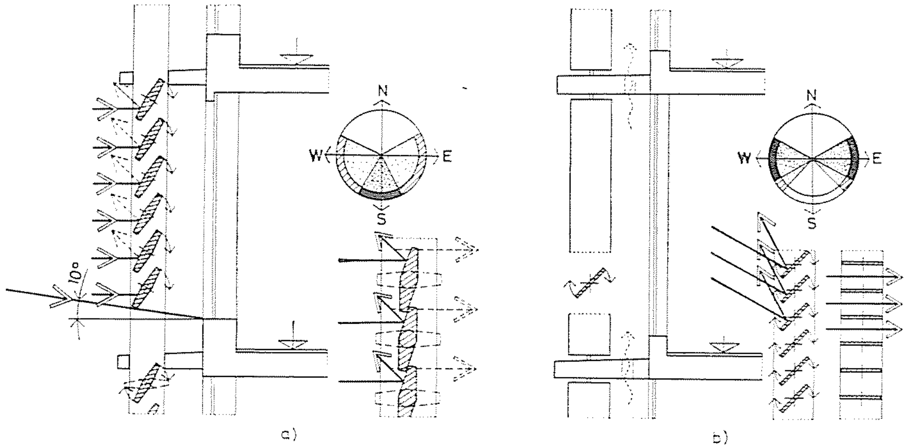

Fig. 15. a) Row of horizontal, mobile lamellae in the vertical plane; b) row of vertical, mobile lamellae

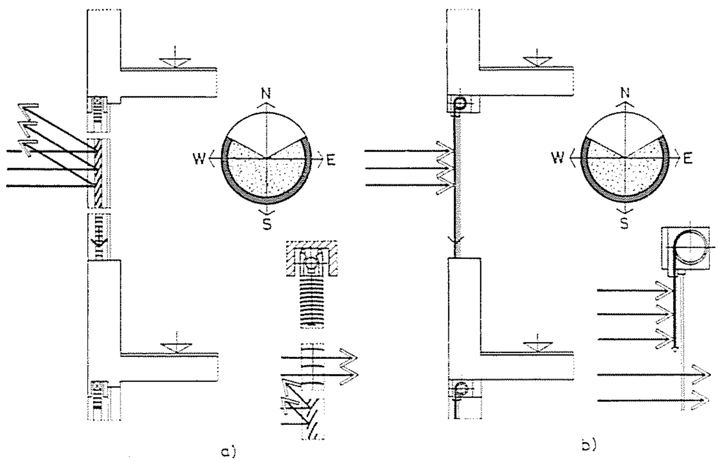

Fig. 16 a) External Venetian blind; b) External canvasses

iv) *Vertical lamellae in vertical plane.* Fixed (r.c., metal or wooden) or mobile (metal or wooden) shades designed for aeration. Fixed types lend themselves on east or west façades, mobile ones also on SE and SW ones (Fig. 15b).

v) *Venetian blinds.* Light damping can be controlled by letting down and turning thin (metal or plastic-coated metal) lamellae. They are especially recommended for south (SE or SW) orientations but are efficient everywhere with lamellae closed (Fig. 16a).

vi) *Canvasses.* Coloured linen light damping structures moving on rails and let down (or pulled up) before the window. They shield against sunshine efficiently in any direction (Fig. 16b).

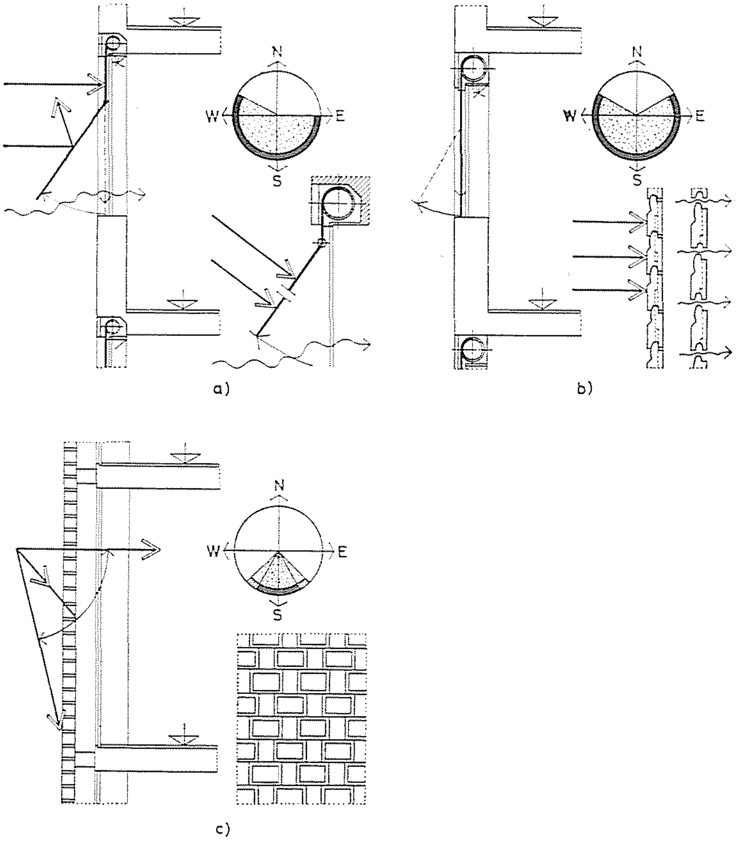

Fig. 17. a) Stayable roller blinds; b) stayable Venetian blinds; c) screen walls in the vertical plane

vii) *Rolling canvas blinds* to be stayed out. Coloured linen light damping structures let down and stayed (for aeration and lookout). Stayed out they are effective for south orientation, and let down, for any (Fig. 17a).

viii) *Venetian blinds* to be propped out. Light obstructing structures of wooden or metal slats. Let down, they are impermeable to light but can be thinned for aeration and stayed out for aeration and lookout. Propped out, they are efficient to south orientation, while let down dense, unpropped, they cause complete darkening (Fig. 17b).

ix) Concrete, artificial stone, ceramic or metal screen walls in the vertical plane. They are efficient for south (SSE, SSW) orientation, to a degree depending on the hollow to solid ratio, on the wall thickness and the slope of units (Fig. 17c).

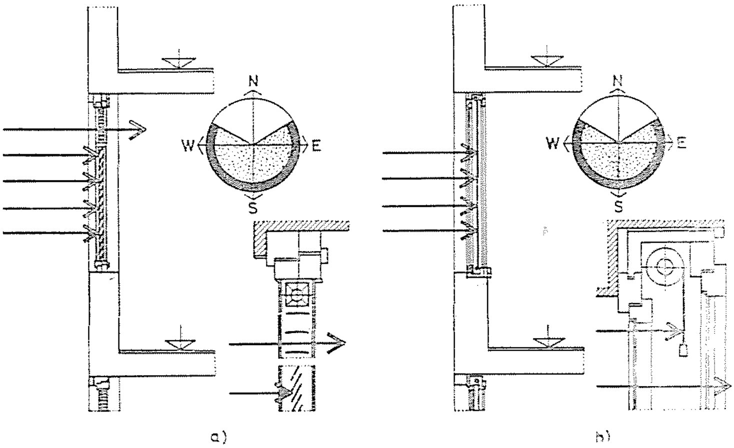

Fig. 18. Examples of inter-pane light damping devices: a) Venetian blind between two glass panes; b) canvas roller blind between two glass panes

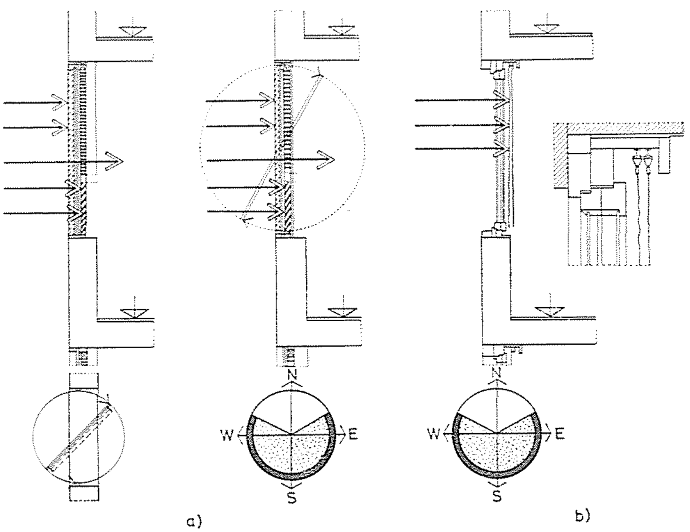

Fig. 19. Interior light damping devices: a) alternatives of internal Venetian blinds getting outside upon turning (swivel and tilting windows); b) internal curtain

4.2. *Inter-pane light damping structures* (Fig. 18)

a) *Venetian blinds.* Metal or plastic-coated metal lamellae between glass panes of united sash or cleaning sash windows, damping light as a function of the position of lamellae let down. Though suit any orientation, they are little efficient because of their position.

b) *Rolling blinds*, linen curtains between outer and inner sashes of double windows. Independent of orientation, they are efficient — though to a low degree — to any orientation.

4.3. *Inner light obstructions* (Fig. 19)

a) *Venetian blinds*. Light excluding structures on window sashes behind the glass (similar to that under viii above). Because of their emplacement, they are useful in any orientation and protected to damage, but little efficient except for some types of tilting and swivel windows where they may get outside and thus become equivalent to those in external position.

b) *Curtains*. Light damping structures of some translucide or opaque or combined fabric hung behind the window, independent of orientation but of low efficiency (depending on material and draping).

Summary

Façade apertures of increasing importance in modern architecture are analyzed from the aspects of building constructions and constructional physics. Beside architectural and structural aspects, also those of energetics and of economy are considered.

Prof. Dr. László Gábor, H-1521 Budapest