AESTHETIC ASPECTS OF SELECTING MATERIALS FOR ENGINEERING STRUCTURES*

By

G. KÁSZONYI

Department of Building Materials, Technical University, Budapest

Received: February 19, 1981

Presented by Associate Prof. Dr. Gy. BALÁZS, Head of Dept.

In his "Testament" F. L. WRIGHT attributes philosophy an importance similar to that of sight for architects.

Throughout historic development, objects produced by building always represented values without being aesthetically valuable. The first constructions of mankind can be considered as utility objects just as the first tools.

From among all utility objects created by man, the building has always been peculiar by functioning always and everywhere as frame for the life of the individual and the society.

This is why buildings — as utility objects or engineering structures — had to have an aspect already by the earliest times satisfying the average sense of beauty of the individual, and the aesthetic demands of the actual society.

"Big-size utility objects" meeting basic material needs created by building are not only "useful" but "beautiful" by meeting aesthetic demands, and in fact, their outstanding specimens are certainly "artistic". Just as the entirety of Reality, also artistic creations (parts of the objective reality) integrate purport and form, underlying their aesthetic appreciation. The system of categories of Marxist—Leninist aesthetics cannot be applied as such for the aesthetic appreciation of engineering structures (non-autonomous artistic creations). Namely, in certain arts — first of all, in architecture and in applied arts — beauty is coupled with direct utilitarian significance (material utility), even their artistic-aesthetic significance is preconditioned by functionality. Engineering creations as "big-size utility objects" take a special place among human creations, since:

a) they are primarily utility objects (industrial, transport, hydraulic etc. engineering structures), thus, other than autonomous artistic creations,

b) they include no (or at most, functional) inner spaces, inaccessible to the classic principles of space art,

c) they are voluminous, hence aesthetic by mass effect,

* Abridged text of the Dr. Techn. Thesis by the Author

d) elements of the outer form (as aesthetic category) are inaccessible to conventional appreciation (as are autonomous arts), they become inner formal elements.

Based on these essential specifics, it has been attempted to establish a modified interpretation and composition of the category system of Marxist—Leninist aesthetics likely to suit aesthetic analysis of engineering structures, or the aesthetic direction of designing (Fig. 1).

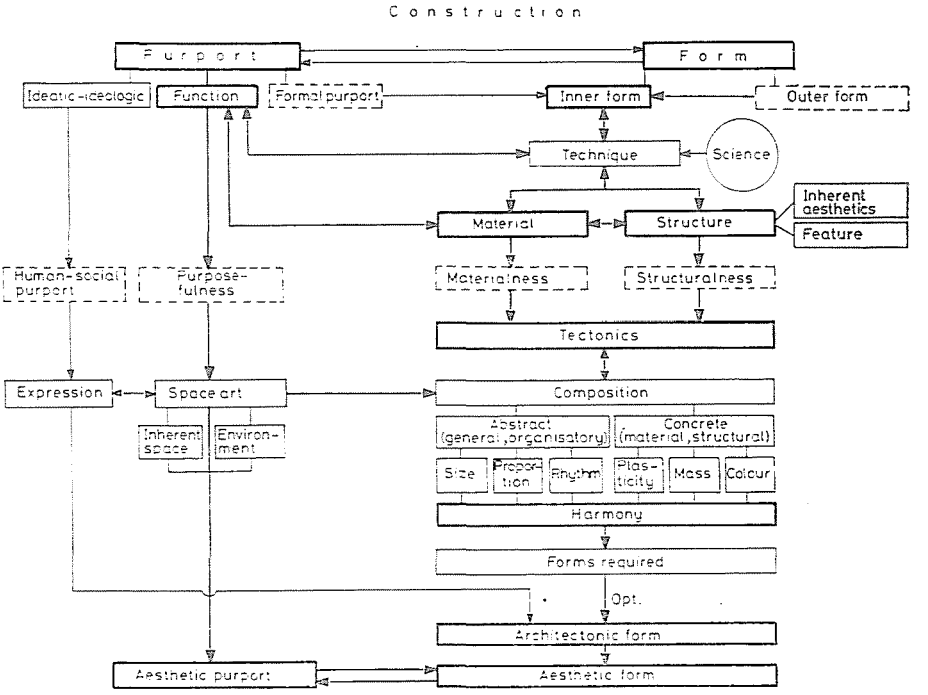

Fig. 1. Terminology of purport and form for the aesthetic evaluation of engineering constructions

Material is the most general concept in philosophy.

ENGELS denied the unity of world to reside in its existence rather than in its materialness.

In course of historical development, man necessarily always was in touch with material, moulding it to his needs and possibilities. The moulded material reacted, in turn, on the conscious human activity. "Humanized" material world became the vehicle of aesthetic values when it raised concepts of regularities in the human mind. In aesthetic meaning, material (stone, wood, metal, concrete) is a medium with visual and sensory form recording creations of the artists. In virtue of its criteria, materialness is an essential component of artistic creation.

Material, as object of artistic creation, is a reality existing objectively, irrespective of the consciousness. The functional demand becomes a function, a concrete creation in the material.

Aesthetic analysis of the material points out two factors fundamental from the aspect of construction:

1. particulars (inner structure, colour, texture etc.),
2. decision over the structure (strength, physical characteristics).

Adequate and conscious utilization of formal possibilities offered by materials is manifest by materialness, the optimum suitability of its strength characteristics against stresses in a given structure is manifest by structuralness.

In general, a form is good and aesthetic if it is in perfect harmony with the inner regularities of the material, discloses the natural beauty of the material, does not deceive but exhibits forces and reactions.

H. VAN DE VELDE is illustrative in stating recent creations to owe their beauty merely to the prevalent principles of reasonable existence and to the exactly purposeful, regular use of materials.

Accordingly, a structure is true, good and elegant if its forces and reactions correspond to material characteristics, thus no stresses in the material it is not typically resistant to arise.

Materials for engineering structures are termed structural, or building materials.

Building materials markedly influence the aspect of engineering structures, they are fundamental for the shape of engineering structures. Durability, mouldability, texture, colour and load capacity of the materials are important factors of aesthetic quality. High-strength materials permit smaller cross sections, more slender, finer lighter-weight structures with finer articulations. A reduced mass raises the feeling of ease.

The development of structural materials and of structures made with them has been a fight between two, opposite endeavours i.e. to ever lighter building materials and to ever higher strengths, as illustrated in Fig. 2. FULLER considered construction to be the art of lightening.

Let us outline now moulding possibilities, aesthetic qualities inherent in each building material.

Building stones

First "natural" abode of man was cave in a rock, an important momentum not only for the development of space and mass notions but determining the first forms of material concept. The "stone building" of nature, the cave

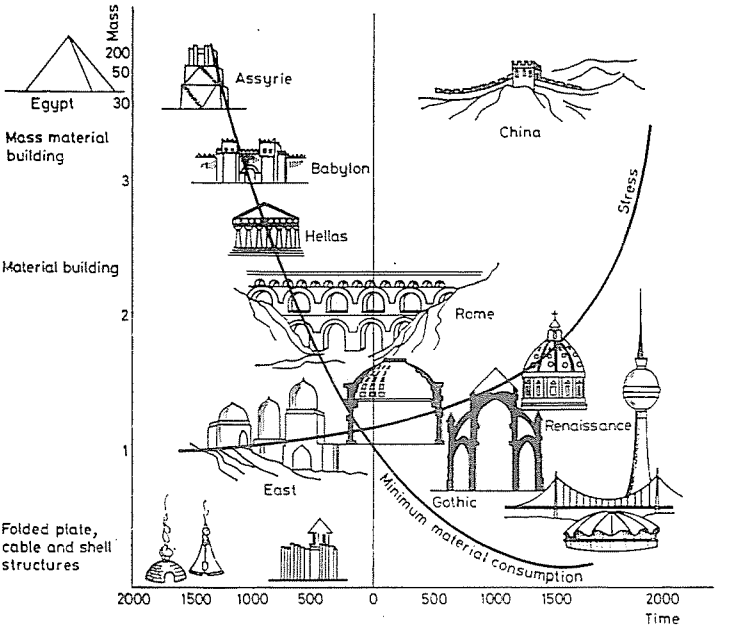

Fig. 2. Fundamental tendencies of the development of structural materials (after [4])

made aware of the strength, durability of stone, at the same time raised the sensation of permanency.

Most important structural materials in the age of mass material building and material building were natural stones. Stone architecture rose in Gothic style to an artistic level. Gothic arched buttresses supporting the solid wall developing only compressions typical of stone are the non-plus-ultra of materially and structurally artistic building.

Recently, natural stone — as structural material — is increasingly displaced by "artificial stone", concrete and reinforced concrete. Former structural application of the stone has gradually shrunken to its cladding, aesthetic qualities (stone claddings of abutments and bridge piers, flagstones for representative structures such as subways etc.).

Building timber

Inhomogeneous, anisotropic, living (organic) timber is one of the first, considerately applied building materials. As natural prototype of human building activity, a tree fallen across a creek creating thereby a "natural bridge" made aware of the use of timber as a structural material. Again, first suspen-

sion bridges made of lianes and vines are the first cable structures where tensile strength of vegetal fibres was recognized.

First human buildings, tents, half-timber adobe huts made use of grown, organic timber. Though, timber structures on piles hint to a developed structural, material knowledge matter. Tree is the ancestor of the column as structural member, a raw tree trunk in form. The first stone columns simulate timber architecture (tapering fluting, evasive capital as remnant of wood fibres spread under load, grooves reminiscent of hoop traces around trunks). Timber is aesthetic by being a "living matter". Since ancient times, man as a natural being feels natural phenomena, materials to be attractive. Timber, as an organic, grown material materializes living matter, even dead, it symbolizes life, warmth, growth, decease to the builder. Variegated colour, texture, pattern of wood are inexhaustible tools of aesthetic design.

Metals

The industrial revolution in the late 18th and early 19th centuries entrained the appearance and rapid extension of iron and steel among building and structural materials. This new material of one- and two-dimensional structures, of a high compressive and tensile strength has displaced tridimensional masses of stone structures, and entrained quite a number of structural and aesthetical facilities. Initially, timber and stone were replaced by the new material of iron, adapting structural and formal solutions arisen for classic structural materials. In course of the history of construction, iron or other structural materials long remained hidden, and even later, they appeared disguised or immaterial. Real meeting points between architecture and civil engineering were bridges and railway station halls. The need of spanning big spaces, recognizance of high-strength steel to be convenient, conscious utilization of moulding possibilities in steel helped its breakthrough in civil engineering.

Aesthetic achievements of structural steel are:

- its high tensile and compressive strength enable it to cover (span) large rooms, at an important modification of spatial approach;
- it raises a feeling of lightness, boldness, ease;
- it replaces the traditional, tridimensional mass forming by bidimensional, exact, precise structures;
- "malleability" in production provides for structurally and formally adequate sections;
- its materialness harmonizes in appearance with that of other materials.

Beside steel, aluminium is a valuable, developing structural material. Its structural aesthetics resides in its homogeneity, anticorrosion, weathering resistance, watertightness and metallic surface. It needs no painting: its colour, lustre and materialness are of a special aesthetic value.

Concrete and reinforced concrete

Perhaps the most extended structural material is concrete both for walls and partitions, and as structural material. It is an artificial building material, an "artificial stone" arising by mixing a binder, water and aggregate, with application possibilities bounded by the way of making: freshly mixed, plastic concrete is cast in shutterings — keeping their form after hardening.

Concrete as a stony material has a high compressive but low tensile strength. It is advantageous by being easy to mould by casting in the proper shuttering but its adverse brittleness, rigidity long hampered its use as a structural material. Already by the beginning of this century, concrete was recognized to offer simultaneous tools to the structural engineer for structural solutions, and to architects for aesthetic solutions (surfaces, masses). While, however, engineering structures (concrete and reinforced concrete bridges, silos, water towers etc.) were made with exposed concrete surface without ulterior treatment, in "architecture" (for houses and public buildings) the load-bearing structure has usually been coated in stone, ceramic tile, or plastered. Concrete dominating the façade necessarily raises peculiar demands to plastic effects and novel architectonics, in particular, division, articulation of surfaces and intensive light-shade effects resulting from plasticity, the possibilities of which offered by concrete being soon discovered and applied in monumental sculpture.

Forms of appearance of concrete and reinforced concrete are:

— exposed concrete proper, truly reproducing the mould inner surface;
— exposed aggregate surface exhibiting the concrete composition;
— surface treated as artificial stone;
— surface vitrified by melting.

Concrete surfacing depends on its material characteristics and technology. The shuttering is responsible for the hardened concrete surface. The design of extended surfaces and masses much depends on the surface texture of the concrete building, to be created by

— disclosing the material composition and inner structure; and
— applying different shuttering systems.

Building ceramics

Burnt clay as an ancestral building material has been applied since the knowledge of fire (12 000—11 000 B.C.). In the philosophical history of material concept due to *Anaximenes*, *Thales*, *Heraklitus* and *Democritus* FIRE, WATER, EARTH and AIR were the four primary elements *(Empedocles)* meaning for the human consciousness the existence of the physical universe, and determining its materialness, and as such, they were the origin and bases of the materialist world concept. The philosophy of *Aristotle* considers the four primary elements already to have aesthetic properties, symbolic concepts as attributes, joined by counterparts of heavy-light, cold-warm, wet-dry. This attribution of concepts is typical of the development of a psycho-physical and emotional man-to-material relation parallel to the mental development.

This is responsible, among others, for the preference to and spread of ceramic buildings materials arising from the union of the "four primary elements", carriers of ideatic significance for man getting to dominate Nature.

The character of brick and clinker masonry depends on the colour, structure of buildings, joints and façade division. Brick masonry is specific by its

— dense screen mesh,
— ruggedness,
— cellularity.

Architectural glasses

Beside steel and reinforced concrete, glass is one of the most frequent building materials in modern architecture, with important aesthetic effects.

Generalization of glass is due to its peculiarities, in particular, it is indispensable by its transparency, light transmission. Further advantages are indeformability, heat resistance, watertightness, ageing resistance, mouldability in manufacture.

Glass transparency is also important both aesthetically and visually. Latest, high-strength glass panes applied for walls and partitions offer unique possibilities of architectural spatiality, such as interpenetration of outer and inner spaces, optically continuous (but physically confined) inner rooms and groups. The possibility of optical interconnection fundamentally affected the relation between structure and its surrounding, creating quite a series of new means of expression. This has been the tool for *Neutra* for the artistic connection of outer and inner spaces. Transparency as a feature was an important factor in the separation between structure and walls, in the unconcealed, open exhibition of the structure. Further aesthetic means are due to the stainability of

glass material for the development of stained glass surfaces. Stained glass mosaics, preferred artistic tools with mystic effect of Gothic architecture, are generally known. Light transmitted by glasses of different colours are tools for the architect to create psychological, emotional, aesthetic impressions as did *Le Corbusier* in the *Ronchamps chapel.*

Materials and neutrality of glass are important aesthetic values permitting harmony with almost any other building material.

Synthetic materials

These chemically produced artificial, organic building materials can be worked and processed by industrial methods. Their recent but fast spreading constructional application is attributed to several technical and aesthetic conveniences such as:

- low density, hence adaptability to lightweight structures (mass formation),
- ease of workability, mouldability (form possibilities),
- usually pleasant aspect (colour, texture etc.),
- proneness to interaction with other materials (sandwich constructions),
- high strength (of glass fibre reinforced polyester).

As structural synthetic material usually glass fibre reinforced polyester is applied. Structures made exclusively of synthetic materials are mainly surface structures (folded plates, pyramids, shells).

Application of synthetic materials may give birth to new forms, or as Italian architect RENZI PIANO put it: "The new materials offered new possibilities of architectural expression. The new material leads us to new forms. Peculiarities of synthetics require a new starting point in design and analysis".

An important fundamental of up-to-date structural design is materialness, an artistic quality due to the respect of boundaries of the selected art and genre, possibly managing the natural structure of the constituent materials. Every material has its inherent applications. Moulding should depend on material properties. In general, that form is good and aesthetic that is in complete harmony with the inherent material properties.

Forms suiting a given material generally did not finalize earlier than a while after its effective utilization. Forms bound to natural, valuable materials have been copied in artificial materials (masonry columns painted to marble, Corinthian capitals made of tinplate or plaster). Instead of simple, natural dynamic conditions, wanton, formal solutions arose, leading to intricate structures, disharmonic masses.

Exposed concrete raises the essential problem of materialness. May materialness be expected from concrete cast in wooden moulds hence imitating the surface of wood?

The indivisibility of material and structure implies that an up-to-date approach to architecture and structural engineering does not strive to conceal how the given structure was made of the given material. The imprint of wooden shuttering material on the concrete surface is no "imitation" of wood since the concrete surface is not intended to look like wood. Behind the grain reminding of the shuttering material, the concrete material, colour, surface texture comes clearly, unambiguously to light.

The demand of a precious aggregate raises an economy problem. To reduce the consumption of an expensive aggregate, technological tricks are applied to keep the special aggregate on the concrete surface. Thereby the concrete as a structural material is separated from its surface, essentially a coating, the pure harmony between material, structure and form is destroyed by an unpleasant dissonance.

Summary

Knowledge of the aesthetic aspects of material selection is indispensable for the creative work of structural designers, a precondition of creating aesthetic engineering structures.

Thus, structural design endeavours to find a logic. maximally functional structural solution taking the material, the demand and the man into consideration, such that it does not counteract material laws, and to find an aesthetic formal solution for it — raising thereby the beauty of logic to the logic of beauty.

References

1. Armuth. A.—Balázs, Gy.—Ujhelyi, J.: Making Aesthetic Concrete Surfaces.* (MTI. No. 4596. Bp. 1967)
2. Balázs, É.: Artistic Design of Concrete Surfaces.* (ÉKME Tudományos Közlemények, 1963.)
3. Bonta, J.: Affiliation of Architecture.* (Épités- és Közlekedéstudományi Közlemények, No. 1—2, 1961.)
4. Büttner, O.—Hampe, E.: Bauwerk — Tragwerk — Tragstruktur. (Berlin, 1976.)
5. Gáborjáni, P.: Determinants of Materialness in Architecture.* Dr. Techn. Thesis. Bp. 1979.
6. Ketoff, S.: Les ingénieurs et l'Architecture. (L'Architecture d'auhourd'hui. 1964. 113—114.)
7. Kilián, J.—Balázs, Gy.: Problems and Possibilities of the Development of Structural Materials of Importance in this Country.* BME Építőa. Tsz. Tud. Közl. No. 21. Budapest (1975).
8. Kászonyi, G.: Aesthetic Problems of Engineering Structures.* Dr. Techn. Thesis. Bp. 1979.
9. Künzel, W.: Sichtbeton im Hoch- und Ingenieurbau. (Düsseldorf, 1965.)
10. Lenin, V. I.: On Arts and Literature.* (Kossuth Kiadó, Bp. 1966.)
11. Leonhardt, F.: Ingenieurbau. (Darmstadt, 1974.)
12. Lukács, Gy.: The Peculiarity of Aesthetics*. (Akadémiai Kiadó, Bp. 1965.)

*In Hungarian

13. MAJOR, M.: Architect — an Engineer and an Artist.* (Magyar Tudomány, No. 7—8. 1967.)
14. MARX—ENGELS: On Arts and Literature.* (Kossuth Kiadó, Bp. 1966.)
15. Marxist—Leninist Aesthetics.* (Textbook) (Kossuth Kiadó, Bp. 1969.)
16. PALOTÁS, L.: Materials for Engineering Structures. 1. General Knowledge of Materials. (Akadémiai Kiadó, Bp. 1979.)
17. PALOTÁS, L.: Design of Engineering Structures with Respect to Aesthetics.* (Mélyépítéstudományi Szemle, No. 7. 1963.)
18. PEVSNER, N.: Pioneers of Modern Design from William Morris to Walter Gropius. Penguin Books, 1974.
19. POGÁNY, F.: The Beautiful Human Environment.* (Gondolat Kiadó, Bp. 1976.)
20. SZIGETI, J.: Timely Questions of Marxist Aesthetics.* (Magyar Tudomány, No. 6. 1967.)
21. TORROJA, E.: Philosophy of Structures. (University of California Pren Berkeley and Los Angeles, 1958.)
22. VANSLOV, V. I.: The Problem of Beautiful.* (Gondolat Kiadó, Bp. 1968.)

Senior Assistant Dr. Gábor KÁSZONYI, H-1521, Budapest

* In Hungarian