THE CRITERION OF MATERIALITY IN ARCHITECTURE

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1. Introduction

The means of expression of architecture is the material. This thesis finds full expression when all the components of architecture form a close unity.

These components are:

1. Function
2. Structure } Form
3. Material }

The resulting construction is characterized by the integrity of the three components. This makes them indispensable preconditions in the construction of an architectural establishment. (Guiding principles related to structure and to intellectual and vulgar functions, respectively, are just tangential problems in the present paper.)

This thesis is an attempt to illustrate the importance of the material.

The history of the use of material is most instructive and of great significance. The outward forms of the material, its morphological and qualitative changes have ever been characteristic of the social and cultural endeavours of the period, as well as of its technical standards.

Works finding expression in the outward form of the material have, of course, a reciprocal effect on the development of human — social, cultural, technical — civilisation following the rules of dialectics.

Until the material has taken its definitive place, the architect may have an influence on its forms of being built in — according to given aspects. From being taken into possession to being used, the material is subjected to the following procedures:

1. Selection of material (generally determined by the function of the future building and by the possibilities natural building materials can offer).

2. Shaping of material (depending on the properties of the material selected, on the state of development of the given building industry and on the art of expression of the architect).

3. Matching and assembly of materials (characterized by the state of technological development of the period, by the experiences of the architect and by the application of research and its results).

The following guiding principles based on natural and cultural philosophical considerations mark out the fields in which scientific research is of unusual importance in making use of *material true to itself* and in the right place.

It should be mentioned about contemporary architecture that in the age of industrial production with mass production prevailing, the observation of most instructive and determinative rules manifesting themselves in nature have fallen more or less into oblivion and the architect's responsibility is often shifted to the solution of technical problems. In another wording this means that *we have got in possession of material power* too *rapidly and it has not been followed by cultural wealth.* Outstanding eminent architects, however, having realized the importance of the subject, turn with their observations again to procedures taking place in nature. There they may always find an answer to fundamental problems of structure, construction and the shaping of material. Nature is thus the primary factor and it is natural phenomena that should be reconstructed to check the correctness of a fictitious model. Observations of nature may help in envolving quite a number of basic principles, the most important ones among them being:

a) Load should be transferred to the load-bearing fundament (the soil) through the possibly shortest route;

b) concentration of load should be avoided, because it may disturb the continuous and uniform utilization of the structure making it contrary to nature;

c) direct load transfer in space is more purposeful than multiple load transfer in plane;

d) the model of maximum efficiency is in harmony with the rule of kinetic resistance. The forms of the dominant structures undergo the rules of nature;

e) the economy and rationality of nature by which it aims at its state of equilibrium by the smallest expenditure of energy should be followed;

f) the abundance of statical (mathematical) solutions should not mislead the architect; unnatural statical patterns resulting from the *impersonal rules* of statics lead to unnatural structures and shapes.

P. L. NERVI, in formulating the ponderable principles of his architectural activity, stated: "Our century has introduced adaptation to nature".

The aim of the present paper is to promote efforts made for a synthesis of natural phenomena and scientific research, in order to find the right proportions.

2. Material translation

(Survival of material moulding modality in a different material)

Building materials are produced and made use of as demanded by the social and economic-technical requirements and erudition of the period. A given material undergoes changes in the hands of architects for a long time until it receives its true shape of expression, the possibility to its being formed *true to the material.*

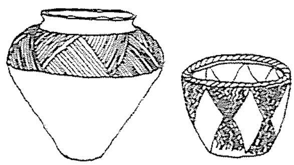

Fig. 1. Ancient mud vessels recalling wickerwork in ornamentation

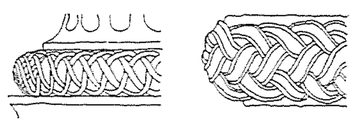

Fig. 2. Translation of strap-twisting on a Greek stone footing

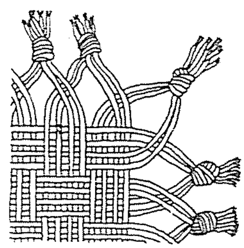

Fig. 3. The appearance of tassel on a simple tissue

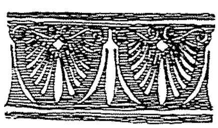

Fig. 4. The shaping of tassel in stone on a Greek ornament in the plain

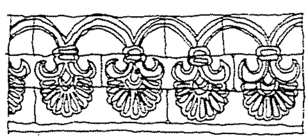

Fig. 5. Old-Persian motif on a glazed tile wall

In the following the concept *material translation* stands for the phenomenon of the transfer of a given means of material moulding from one material to another. When ways of shaping, working, expressive forms convenient for a proved, common material are translated to a material just taken in use, the architect needs a longer period of time to be able to lend the new material a form of expression originating in its own inner structure. Human eyes and taste must get accomodated to the character of the new material, to its specific properties. From this aspect, the inertia of industrial activity to changes is of importance. The examples in Figs. 1 through 8, are demonstrating material translation phenomena.

These phenomena are for the most part external manifestations of architectural factors. While for example for the structural equilibrium the architect must keep to exact rules, surfacing is often incorrect, independent from the structure under the misunderstood pretext of "architectural freedom". Even a fully aesthetical shape given to an object means full possession of the economic

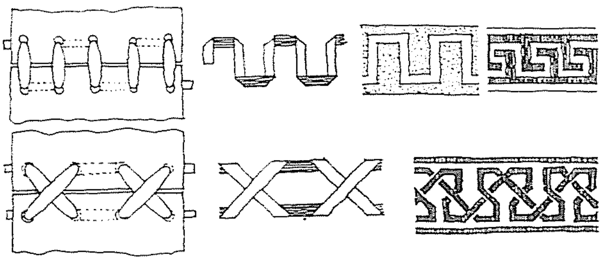

Fig. 6. Two ways of sewing together and Greek motifs developed from them

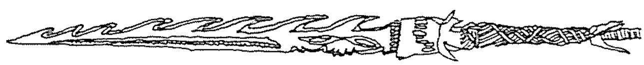

Fig. 7. New-Guinean arrow

Fig. 8. Bronze Age spearhead with carved imitation of the binding

and technical elements that are definitive for the given object and from which it has organically developed. The character of the object depends on the manner in which the designer arranges the correlated masses, materials and colours. *It is in correlation of masses that the intellectual value of the object comes to expression*, rather than in the external requisites of decoration or profile.

3. The dialectics of material transmutation. Accomodation

The questions of natural philosophical character connected with our subject fall into two categories: one is related to *the structure of the material*, the other to the frame in which the material exists i.e. to *space and time.*

Nature — in which we live, and in which the space and material organizing activity of the architect takes place, is an indissociable four-dimensional order, according to our present knowledge, including three-dimensional space with time as the fourth vector.

The material the architect uses is of spatial structure and of microstructural character without exception. In selection and building-in, the characteristics following from the inner properties of the material must be taken into consideration as they being responsible for e.g. the material surfacing, the colour etc. and even for the durability.

The inherent forms of the material are based on given regularities, find expression in the natural structure of the material. The steric crystalline structure of the material, in permanent motion, is an ephemeral result of the constant changes in the state of the material; it changes with changing conditions governed by the dialectical rule of interaction.

The analytical thinking of our time demands to judge things ever more by their deep-lying inner relationships, rather than by external, superficial phenomena, and to bring aesthetical purport in close connection with the truth of the inner structure.

Starting from the spatial character of materials, the following conclusions may be drawn. The selected basic material will change its shape, colour and properties as a function of time in the entire course of its industrial processing, up to use or even after having been built in, following the changes of its inner crystalline structure (transmutation). The proper use of the material requires the knowledge of its inner structure. Atoms within the crystal are arranged according to rules following from their own properties and what we call a space lattice is practically an expression of definite conditions between definite atoms. All changes in the material are expressed by changes in the space lattice. The properties and characteristics of building materials and their surfaces originate in the inner structure of the material.

The materials are resistant to a pretty wide range of external influences (accomodation, Figs 9. and 10). A material begins to disintegrate when its space lattice loses its ability to accomodate or more exactly, when it cannot return to its original crystalline state any more. This may have internal and external reasons.

An optical registration of the inner structure permits conclusions to be drawn on some of its properties.

Table 1

Internal reasons	External reasons
1. Natural inner disintegration. (Primarily with organic materials.)	1. Changes upon natural external influences (mechanical, chemical etc.)
2. Disintegration of artificially built-up crystal systems — molecular relations (e.g. in high molar weight polymers).	2. As a consequence of interrelations between incorrectly combined materials (e.g. assembly of a moisture absorbing material sensitive to moisture).

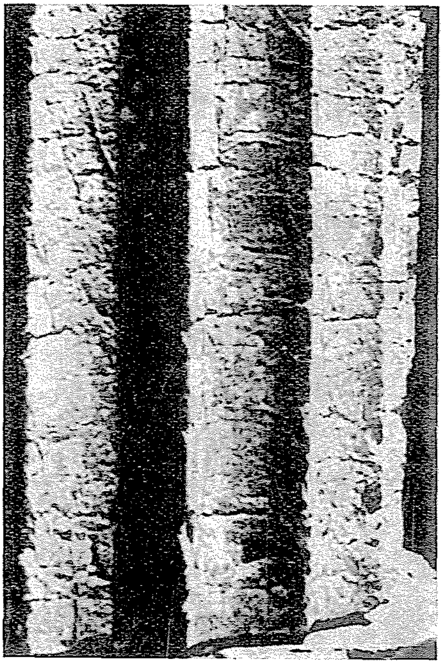

Fig. 9. Natural accomodation

Fig. 10. Disturbed accomodation

Figs 11 and 12 are schematic pictures of X-radiographies of the crystalline structure of a faulty and of a perfect wire weld, respectively. The first figure is of lower load capacity than the correct one. The two examples are

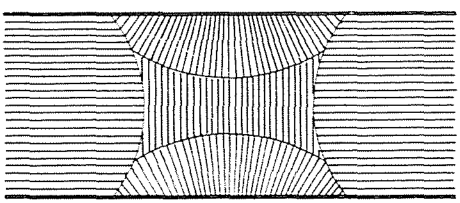

Fig. 11. Schematic diagram of the incorrectly arranged crystalline structure

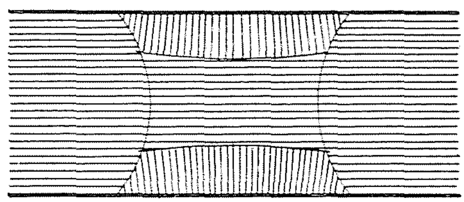

Fig. 12. Schematic diagram of the correctly arranged crystalline structure

illustrative enough of the definitive effect of inner structure on the behaviour of the material to *make the properties — in our case acquired properties — of the material controllable and optically traceable upon the structural built-up.* (Another example is to produce crank-shafts by forging instead of casting with a view to the continuity of the crystal system and higher torsional and flexural moment bearing capacity.)

4. Conditions of compatibility and isochronous ageing of materials assembled into structures

Destination, social-economical conditions of buildings require structures to satisfy both service demands and aesthetical-optical aspects as a function of time. In other words this means that the materials making up the structure and exposed to different influences should behave about similarly during a given period. (This has gained special importance nowadays in view of the stress laid on modern requirements and technical rentability.)

The observation of the equilibrium of inner and outer "loads" is also most desirable. The characteristics of these two influences are as follows:

Table 2

I, Reasons of inner changes:	Examples:	II. Reasons of outer changes:	Examples:
1. Chemical incompatibility of two or more elements	Metal in acid	1. Outer physical effects	Primarily mechanical (e.g. denudation), thermal effects, radiation
2. Physical incompatibility of two or more elements	Mechanical e.g. overloads on insulations	2. Outer aggressive effects	E.g. Sulphur dioxide content of the atmosphere, flue gases, etc.
3. Harmful material radiations	Structural rearrangement		
4. Deterioration and deformation caused by structural disequilibrium	Improper use, lack of suitable expansion joints		

The photos presented show the surface of one and the same basic material with different joints. In the first case the correlation is abnormal since the joint system asserts itself beyond compatibility in the building element and this results in uneven wear (Fig. 13).

The second picture illustrates the phenomenon of accomodation where the assembled materials are balanced (Fig. 14).

The third picture illustrates a case reciprocal to the first one. In this case the basic element has proved more resistant than the joint system (Fig. 15).

It is seen how the finding of proper compositions, the determination of material quality are of importance, with effects in time.

In old times architects designed structures for longevity — as required by the conditions of the age. (The main reasons underlying this custom were of social and ideological nature.) In our time, when social, cultural and

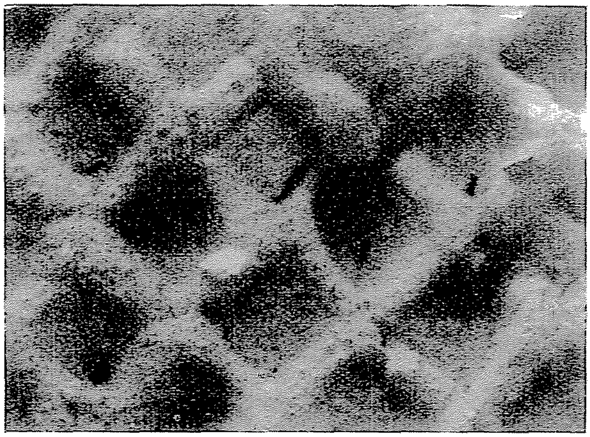

Fig. 13. Strong binder, weak building unit

Fig. 14. Equilibrium of accomodation

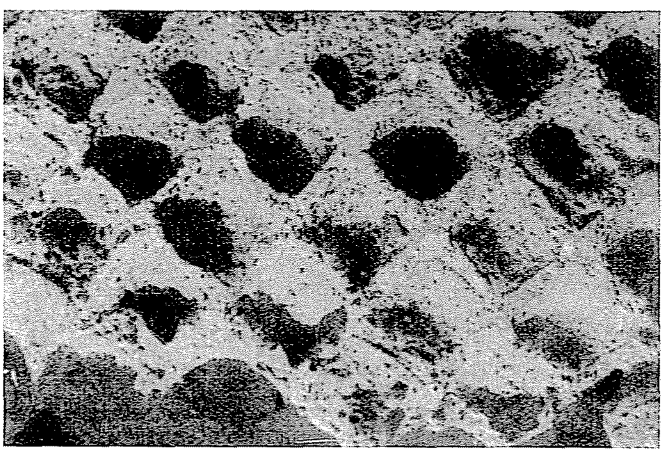

Fig. 15. Poor quality binder, firm building unit

technical changes follow each other in quick succession, the life foreseen for a building is much shorter (about 80 to 120 years for living houses). This makes it imperative to test the designated materials in laboratory from the following aspects:

1. Compatibility (as discussed in Table 2).
2. Durability (ageing), especially with respect to plastics.
3. Determination of simultaneous resistance to outer effects as a function of time.

Such examinations are especially important because it is not reasonable to replace much of the components of an establishment before it ended its service of destination. In the case of an uneven use, an economically disadvantageous reconstruction of parts of the building is necessary. (Let us take an example from another branch, from motor car production, where optimum dimensioning of the body is determined by the use of the engine for 2—3 years, which means a co-ordination of the components for the same period of time.) In some countries the sanitary equipment of the buildings is planned to last 10 to 15 years longer than the structural parts. This system was born from least-cost calculations. It means greater operational safety during its use, on the one hand, and a minimum of investment increase, of special advantage by the end of its lifetime, on the other.

A comparison between amortizations planned for shorter or longer periods clearly demonstrate great differences in the process of wearing during the same period. Namely, assuming uniform wear for both cases and projected to the same unit of time, the ageing coefficient of the equipment designed for a shorter lifetime must be raised in order to keep it after some time at the level of the building designed for a longer life.

It follows from the above that only structures whose components are ageing uniformly may be considered economical. In the opposite case partial investments before total unserviceability make the building uneconomical.

5. Quality

The activity of the architect is to shape the material. In this our age of mass production such kind of work may be founded on scientific knowledge only. The old masters had no such theoretical qualifications as their late followers, the architects of today, are given. They had, however, an experience on the nature of materials as they worked with them themselves. They knew about the forms in which natural stone may be used, about the hidden properties of basalt and those of granite, could judge what calls for marble and what the steel structure can bear. They kneaded, touched, carved, chiseled and cast the material with own hands and knew the soul of the material by gathering empirical informations on its natural behaviour. This direct experience, this practical knowledge may be extended and deepened by theoretical knowledge in chemistry, physics and studies into the various kinds of materials but cannot be substituted by it.

Our present task is to return to the material and see for ourselves what possibilities for handling it can offer, what texture and colour can concrete, steel, ceramics etc. offer.

It is not enough to know the specific weight, the thermal properties of materials as these are not the only differences in them but they differ also e. g. in touch. A knowledge of materials helps the architect in deciding upon one or another of them, in their structural development and in the establishment of connections between various materials. In the course of a given task, materials are to be united into a compositional unit according to defined functions, with due consideration given to the materials, structures, formal system and colours of the environment. The old masters lived — so to say — together with the material and their knowledge was intuitive and empirical. It is essential that — beyond having acquired theoretical knowledge — a modern architect should get somewhat closer to material in order to learn its natural properties, its *quality forms* also by experience.

Industrial companies produce an endless line of a great variety of building materials, and architects have more often than not the single possibility to select the material to be used on hand of catalogues and colour charts. An advantage when taking a decision have those who know about the structural and shaping possibilities of materials as it is the principle of materiality that must prevail also in the quality of the latest architectural products.

From naturally handled materials (in ancient cultures) people expected a quality similar to what they could see in the creative work of nature and in most of the products leaving manufactures.

Naturally, with the spreading of civilization and of mechanical culture, people wish to lend higher theoretical and intellectual values to the qualified material and product they create, a precondition of this being perfect quality.

In the period of handicraft, production was restricted to small series each item of which was made with the control and sensitivity of hands. Industrial objects, however perfect their workmanship and although they may be better than the artisan's work, have lost contact with this sensitivity and with human relations. We may go as far as to say that in the creations of an artisan there are certain mistakes which only emphasize that *man has handled them in direct contact.*

Series production will have a real value when material takes the form corresponding to its nature possibly leaving its purport intact as it will be forbidden to issue products not true to material.

It is important for the design that *it should not be considered a mechanical function only but accepted also as a means of intellectual expression.* (In Finland and Sweden where the culture of objects has reached a high level, industrial companies employ only industrial designers of high qualifications even for their mass products.)

A knowledge of material has come into the foreground today as just because of mass production, we have got physically farther from it. It is essential to know the materials or to refresh our knowledge of them because with giving up manual handling we have lost something that *we can never regain by mechanical production.* At the time of manufactures, human spirit was in direct contact with the material and had an influence on the spectator. In mechanical handling we wish to give some additional value instead of it, offered by the new technology: *almost unlimited possibilities of shaping the material.*

It follows from the above that since the giant apparatus of mechanical handling has been inserted between man and the material to be handled, the place of directed connections with the material must be taken by a high level of quality. In this way, we may get compensated for a lost direct connection with the material. The quality desired can be determined on scientific and optical-aesthetical bases by comparative calculations and laboratory examinations.

Quality means the measurable standard of the applicability and aesthetic appearance of the material that is adequate to the momentary standard of the intellectual state of development of the human mind.

Trueness to the material is not so obvious today as it was in the time of manual production since materials are constantly changing and leave the producers in later and newer forms. It also takes some time to be able to define trueness to material and quality at the given level.

6. Definition of materiality

An architect shaping nature solves his problems by means of the material, by its forms of motion. Plants filling out the space appear in various forms of the material. Partly *the inner properties of the material,* its chemical and physical parameters must be considered, and partly the technical and optical (aesthetical) aspects following from the former. In the course of their designing and building activity, architect and building engineer can grasp the aesthetical values of the materials they apply also by knowledge of their inner properties.

In compliance with the principle of materiality *the economy of nature shall be adopted. This means that given materials are suitable for the creation of given shapes only and that in a given case only.* These will lend the desired practicability and harmony of the resulting product. Only a work made with an eye on the rules of the material, counting with them and making use of them may be accepted as a creation true to the material.

Even primitive man formed ideas about the phenomena he met in his everyday life. He knew, for instance, that a stone will always fall on its flat side and never on the narrow one. He had every reason to accept this as a regularity and as something that is good and that — after all — could satisfy also his aesthetical demands. Thus he built his primitive constructions also by laying stones on the flat side — as he found it "statically" correct in nature. As to artificial products, only those are felt beautiful that in some way or another are connected with our experience gathered on pre-existing material. (That is why

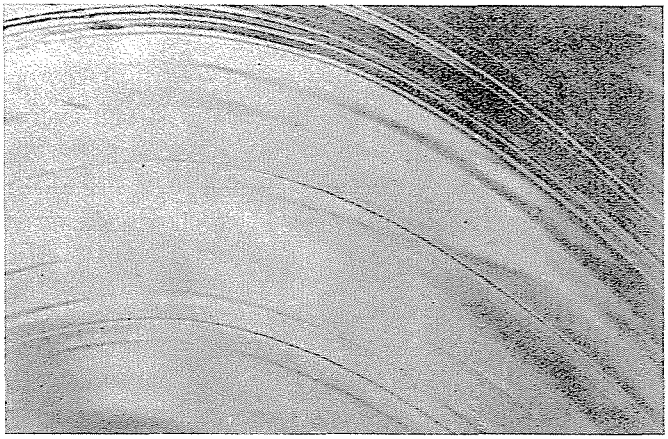

Fig. 16. Glass from the glass-house

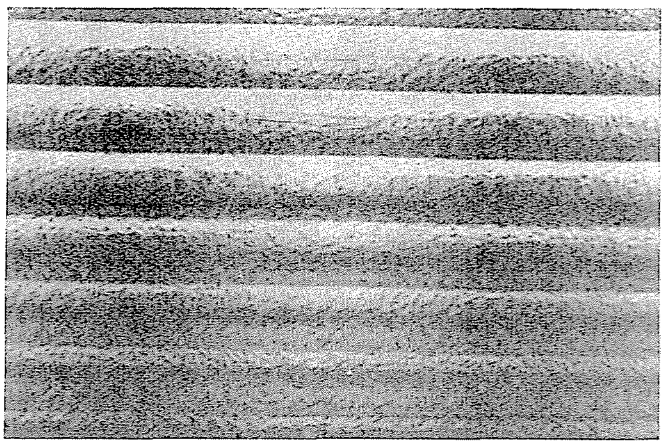

Fig. 17. Cathedral glass (Application true to the material)

glass-house glass shaped in liquid state in its material is found fine and true to the material and something unnatural is seen in ground glass.) (Figs 16, 17, 18.)

A material may fit into the entity of a work when its normal properties comply with the demands set to it. *A material becomes intellectual, a bearer of aesthetic values when it evokes the idea of rules in our consciousness.* If the expression following from the inner nature of the material prevails, the material will be perfect in use and we may call it aesthetical as it satisfies our demand for harmony. The same idea as Paul Weiss put it: "In final analysis any shape we are looking at has a history and is the result of a long process of development. As in this sense every shape is a momentary cross-section of a flow of shaping

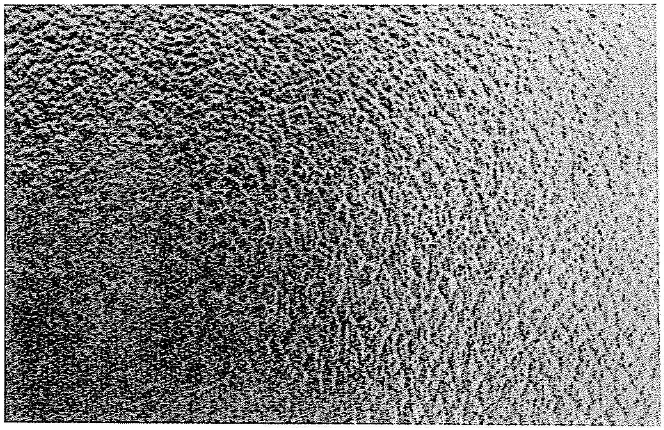

Fig. 18. Cathedral glass (Application true to the material)

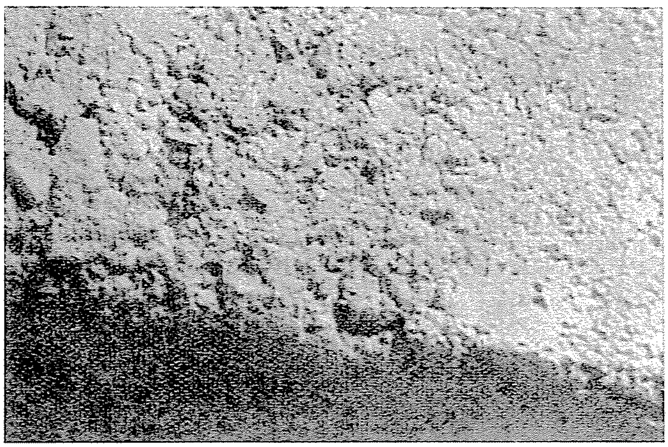

Fig. 19. Concrete structure

and transforming processes, what we admire as beauty and order is an index of the interrelation of moments in development. Consequently, the beauty of shapes is based on the regularities of their evolution."

A positive knowledge of the material is indispensable for an architect. And just because of this, practical experience in addition to theoretical knowledge of the material is most essential. The fact that properly handled material may be beautiful and that surface shaping and form are not independent from the structure but stand in close unity with it, may become a direct cognition. It is not by mere chance that the realization of the natural beauty of materials and the aim to make use of it has come into the foreground in architecture. Natural wood, textiles, exposed concrete, brick, stone, ceramics, fire-clay and refined aluminium find ample application in indoor and outdoor space and we think to discover their beauty in the natural structure and colour of the material. If we wish to make use of the advantages of natural appearance *we must keep to the principle of materiality to the last as an indispensable, though not only, condition.*

Summary

The architecture has the building material as means of expression. The architect can make use of the accentuation of its role.

Fundamentals of the use true to the material permit to exploit aesthetical possibilities hidden in the internal structure of the material. Principles of selecting, moulding and composing materials create a close correlation between aesthetic content and truths of the internal structure.

Problems of importance are the ability of accomodation of the building material, conditions of uniform lifetime throughout the structure, principles of quality and materiality by artisanal and by mechanical means.

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