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THE BUILDING AND ITS ENVIRONMENT

Gergely Molnárka
e-mail:mg352@hszk.bme.hu
Department Of Building Construction
Technical University of Budapest
Phone: 463-1306 Fax: 463-3949
1111. Budapest, Műegyetem rkp. 3. K. II. 26.
Consultant: Dr. Katalin Preisich
Faculty Of Architecture And Building Construction
Széchenyi István University of Applied Sciences, Győr
Phone: 96/503-454 Fax: 96/503-450
9026 Győr, Hédervári u. 3. D503.
Consultant: Prof. Dr. Attila Koppány

ABSTRACT: The following study examines the possibilities of taking the ecological considerations into account in the system of building maintenance and building pathology. The goal of the author is to construe the sustainable development and involve into the mechanism of decision-making, furthermore bringing the financial rationalization of building maintenance up to date and analyzing the options of the use of the elements of ecology. The bases of the development of the fault catalogue, as a technical aid in the process of building maintenance show the interrelations between the building and its environment.

1. INTRODUCTION

The environmental problems, which are getting acquainted and admitted in wider circles, raise questions on the area of architecture and building engineering. The built environment contributes to the formation of experienced crisis. The fast growth of population – by a previous estimation the number of the men on Earth will access ten thousand million in 2050 [1] – evokes that the stock of the building has to be doubled (approximately) in the next hundred years. The knowledge that the traditional energy sources are limited makes serious troubles for the building technology. The 25% of total energy consumption in Hungary is directed to the operation of houses, that means 300 Petajoule (one Petajoule equals with the heating value of 24 million kgs of petrol) [2]. From another approach, the 40% of the total power consumption is intended for erecting, using and demolishing houses.

Nowadays it became clear that the present process can not be upheld in the long run, for the interest of the future one must reach a change of attitude in the society of architects. The proper way to the solution of satisfying every demand on the lowest energy consumption and environmental loading has to be found. Researches of the interactions between built environment and nature and studies of the alternatives of sustainable development are on progress on several areas of building sciences in the same time.

One must consider a sort of leap forward that on the field of standardization, higher building physical requirements are laid against the new constructions. The materials and structures, which are built into the new houses have better vapor diffusion and heat insulation parameters. During the selection of building construction the energy needs and the emission of their manufacture, transportation and application may become a serious consideration.

The process of release of more and more power station based on traditional, non-renewable energy sources with solar cells in houses – which help to harness all the advantages of solar radiation and heating – and with wind power stations can be seen as the spreading of ecologic thought.

The more centuries old building materials and constructions of rural architecture live their Renaissance again. It is not only a wave of nostalgia but the regard to the natural materials for the prevention of environment as well. The building elements – as the adobe –, which came to the limelight for the experts of building sciences, seem to be valuable from many aspects for the planning of the future. They may expect appreciations from their applicants because of their advantages: the fabrication, the size and location of their source, moreover their relation with the nature. The degree of using adobe that is inconceivable from the view of statics and has significantly different properties from the materials used today may be increased by the fact that its raw material can be found almost everywhere, and he energy needs of its manufacturing is the 3% of the fabrication of “traditional” bricks [3].

The protection of the existing built settings also can be seen as the token of “staying alive”. The interaction between the natural and artificial environment is obvious, so one can state that beside the prevention of buildings that recall past civilizations and other important houses one should emphasize the *experience-based maintenance and improvement* of other *buildings*. From the sight of ecology the pulling down is just a station in the life of building constructions, where a decision is made about the possible solutions of reuse, application or, at the end, about their selective recycling as waste.

The examination of the last area of questions and the building pathologic aspects can be a background information for decision-making, and show the part of foresight in construction design and the mechanism of choice of structures.

2. THE MECHANISM OF BUILDING MAINTENANCE

The buildings have specific properties. The main features are: long life span, possible partial or total function-changes by the influence of technical and social development and the high value of them.

The using up of buildings is such a process, where the laws and principles of sciences (Physics, Biology, Chemistry, etc.) and Economics take effect equally. The objective system of building maintenance has to be built on these laws and principles.

2.1. The Approach of Building Maintenance by the Classical Economics

The buildings take part in the social reproduction directly (power station, industries, offices, etc) or indirectly (dwellings). From another way: they have economic functions. During serving their function the buildings suffer from physical abrasion, become older. Their signs can be kept an eye on ethical ageing, too. The value of amortization that originates from the process of ageing – from the sight of economics – “migrates” to the value of the products, which are manufactured in the examined building. This “migration” can not be shown properly in every case, i.e. dwellings and apartment houses.

For the economic description of buildings, as implements, one must know their own attributes, like they are localized, their accomplishment takes a long time, and that they go through abrasion even they are not in use.

The Optimal Life Span Of Buildings [4]

To get to know the main features and the substance of the economic calculation a simple and conspicuous example can help. The examination below analyzes the life of a new, not inbuilt pitched roof. The short structural description of the construction is: the load bearing construction is timber roof with traditional joint with steel supplements, slate shell made of asbestos cement and zinc plate sheet metal eaves. The construction has to be examined on its weakest point, which is, as the pathologic examinations demonstrate, at the score of the roof

Construction	Relative Experimental Value	Life Span Compared To Each Others	
		In Case of Deterioration	Without Deterioration
1st class pinewood roof	4v	2y	6.5y
Steel supplements	V	0.5y	4y
Slate shell	2v	y	y
Zinc plate sheet metal	3v	0.33y	0.5y

Table 1: Example for the Economic Calculation of Building Maintenance

In this example the relative experimental values and the life spans of constructions are merely information for presenting the calculation.

The passage quoted below studies two extremities: in the first case the construction is under continuous control. The deteriorations are being prepared; the old elements are being changed. The other extreme case is when the abrasion and weakening process is not broken by external intervention, the components are not changed, the roof is “left to itself”.

The life of gathering of the constructions is examined from the point of their creation to the last moment of the total consuming of the timber construction. In our example, the amortization is interesting only in this scope, because the renovation of the load-bearing element involves the inspection of other elements as well.

1	Pinewood Construction
2	Slate Shell
3	Tinning
4	Steel Supplements
kr	Residue of Values
n	Life Span

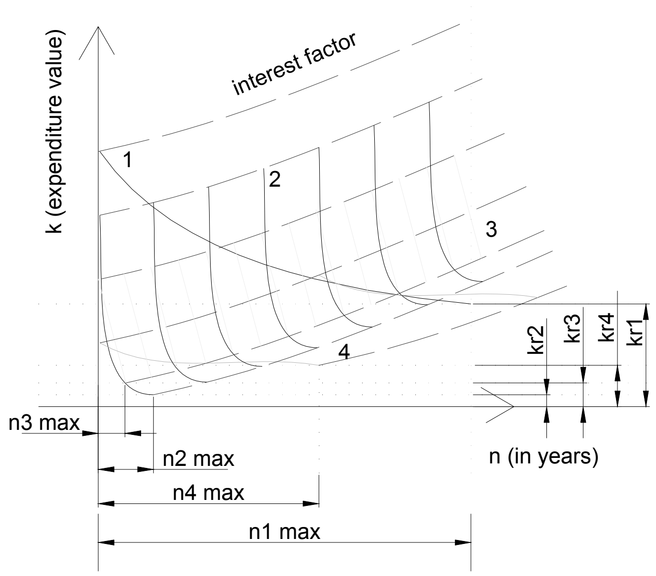

Figure 1: Extreme Example of Building Maintenance

1	Pinewood Construction
2	Slate Shell
3	Tinning
4	Steel Supplements
kr	Residue of Values
n	Life Span

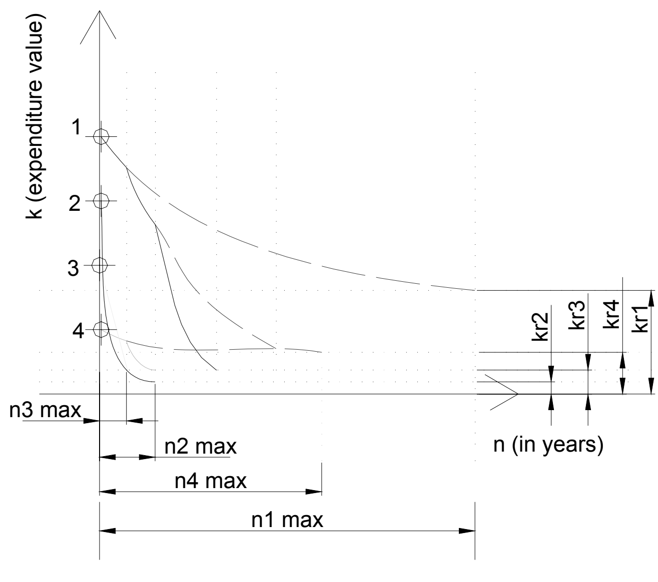

Figure 2: Total Amortization of Construction as a Result of the Lack of Building Maintenance

In the first case (Figure1.) the life of examined construction is united from more consecutive cycles, which take until the total amortization of the whole construction happens. In that time only the load-bearing construction becomes worthless, the supplementary components have rest of their life and value. Keeping the interest factor in sight raises more questions in connection with the value of the different elements in the same moment. It is easy to recognize that such a way of maintenance is not the best solution, when the economic factor has an important role, because the value of the elements mentioned above are different in the same instant. This attitude can be acceptable just in case of monuments and other important buildings.

In the second condition (Figure 2.) a quick fall is observable, which occurs in case of wrongly preserved buildings. This state results much faster than the natural process. The premature weakening of constructions is not beneficial, too, and in addition, it may endanger other building parts. The curve that describes the life of the timber structure breaks in two points: the first moment is the falling down of tinning; the second is the fracture of the steel supplements. Aside from the element, which suffers the fastest fail none of the part of the construction will achieve its own optimal lifetime.

From the comparison above it is noticeable easily that the maintenance, which ensures the financiality of the construction will be a point of the interval between this two extremes. The optimal life span of the construction is that point on the expenditure/time coordinate system, where the state that the construction lives the longest life with the less cost is true. Pulling the construction down before that moment makes the existing construction worthless, maintaining after that moment withdraws amount unnecessarily

The optimal life span of constructions can be determined with the help of the following mathematical model:

$$k = \frac{K+\sum_{t=1}^{z} K_t * \mu_{it} + \sum_{i=1}^{n} (\ddot{U}_{é}+\ddot{U}_{ü}+F_f) * \mu_i + \sum_{c=1}^{v} Fe * \mu_{ie}}{n} \qquad (1)$$

where the letters mean:

k: the yearly average specific experimental value;

K: experiment of the single building of construction;

K_t: the experiment of the repeated building of the solutions in the examined structure, which have shorter life than the supposed total life span;

μ_{it}: the discount factor belongs to the year of arising of K_t;

z: the number of repeated building of the solutions in the examined structure, which have shorter life than the supposed total life span;

$\ddot{U}_{é}$: the yearly amount of operation of the structure;

$\ddot{U}_{ü}$: the yearly value of loss or/and extra experiment of the amortization of the construction deriving from the production, as the function of the construction;

F_t: the yearly experiments of continuous building maintenance

μ_i: the discount factor of the i^{th} year;

n: the supposed life span of the construction (in year);

F_e: the experiment value of a maintenance cycle, which occurs periodically in the life of construction;

μ_{ie}: the discount factor of the year of the maintenance cycle;

v: the number of maintenance cycle during the supposed life span of the construction.

To determine the discount factor the formula is:

$$\mu = q^{-n} \qquad (2)$$

where the letters are:

μ: the discount factor;

q: the factor of interest;

n: the number of years.

The counted “k” values, based on the supposed life span placing to the coordinate system one can construct such a curve, whose idealistic geometric shape is a curve of a square equation. The horizontal tangent at the deepest point of that curve gives the optimal life span of the examined construction (see Figure 3).

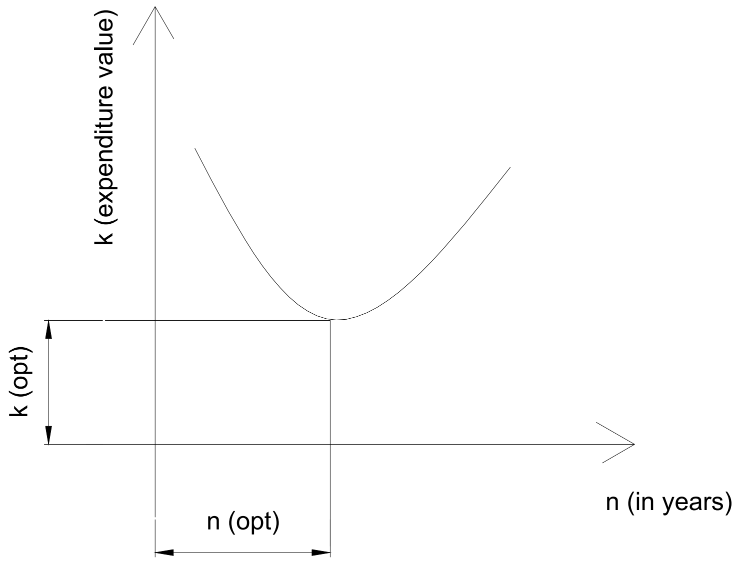

Figure 3: The Optimal Life Span of the Building

The process of using up of the building – as it can be seen in the previous example – is indeed influenced by the maintenance actions. The Figure 4. illustrates the characteristics curve of this process, keeping the maintenance in view.

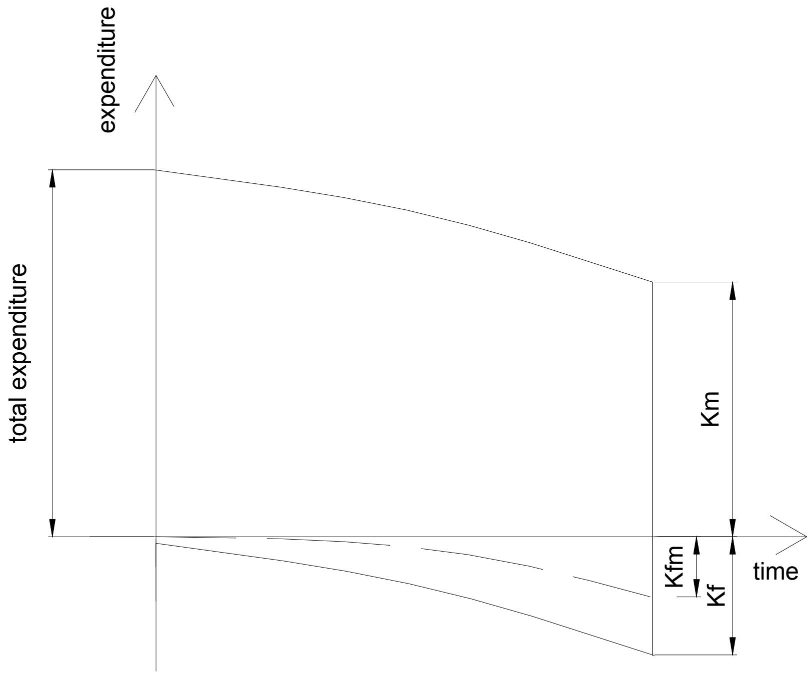

Figure 4: The Characteristics Curve of Using Up With the Maintenance Process

The marks of the figure are:
K_m: the residue of the experiment of execution at the moment of pulling down;
K_f: the maintenance cost during the total lifetime of the construction;
K_{fm}: the residue of the maintenance cost at the moment of pulling down.

2.2. Inclusion of Externalisms

Nowadays the costs, the experiments and the process of falling of buildings can not be determined on such unambiguous way. The economic analysis example about the roof construction mentioned above operates the building as a closed system, from planning to demolishing.

With the facts of the limited energy- and raw material sources the method of building can be describe that something is made of some indispensable thing with a lot of energy, and it is maintained and operated for a while with the utilization of energy, and at the end it is taken into pieces (with the use of power); these issued parts may pollute the nature further.

Ecology found out a (more or less) solution to determine the environmental problems with economic principles, which is inexplicable in the classical Economics. Evolving the external concepts to the economic calculations made a sort of paradigm change on the area of economics. Although there is an argument among experts that one can describe all of the green trouble with the tools of economics, but it is stated that the environmental damages can be followed in some automatic methods: i.e. in the degree of difference between the prices of real estates.

Until the moment, when the mentality and the way of thought in the environmental questions will be changed radically, to have the ecological consideration in sight is the task of the state. With the assistance of proper implements – sanctions (penalties, taxes), rewarding (tax allowances), orders, etc. – the interests of nature may have greater respects.

With the consideration of sustainable development a fundamental conversion is attainable in the method of construction planning and in the choice of structures. On the list of preferences of rational decision-making the factors of natural world will have key positions.

Focusing To The Alternatives Of Building Construction

The mechanism of conscious method of choice of building construction and the decision-making is depictable conspicuously with the help of criteria matrix that is a method used in the value analysis (see table 2). This method applies an easily visible matrix, which reveals the order of aspects (which is not often clear even for the decision-maker).

The order of these considerations differs for every participants. The investor seldom makes decision on the same basis as the designer. The next example is fictious; it merely introduces how the system operates. In the case below the decision of the vertical load-bearing material and structure can be seen. For choosing the main consideration of the decision-making the definition and of categories and delimiting them needs further studies, which is outside of the subject of this article.

The alternatives of the constructions are: timber frame, steel frame, aluminum frame, and traditional brick wall.

The aspects in choosing the constructions:

- The costs of manufacturing, energy needs;
- The appearance, aesthetical and other architectural contents;
- The cost of execution (the transportation, erection, time-dependent factors, etc. are included);
- Environmental loadings (the limited raw sources and the litters at the time of pull down);
- Life span and maintenance (immunity against exterior effects);
- The “radiation” of construction (physical phenomena).

Through this method can keep the environmental effects in mind. The result of the matrix analysis could have been approximately predicted but the position of reinforced concrete seems interesting.

But inside the complex building industry sanctioning the ecological loading and the rewarding the consideration of nature access the different participants through the “costs” factor. the problem with this action is that the amount, which is paid for protecting the environment, can not be found easily in this category. The only way to solve the arisen question is to implant the main features of sustainable development in the public thought.

How Important	
4	Major Preference
3	Medium Preference
2	Minor Preference
1	No Preference, Each Scored One Point

	A. Cost of Manufacture	B. Aesthetical, Architectural Aspects	C. Cost of Execution	D. Environmental Loading	E. Life Span - Maintenance	F. Physiological Effect of Construction
A. Cost of Manufacture	x	B2	AC	D4	E3	A2
B. Aesthetical, Architectural Aspects	B2	x	B3	BD	B4	BF
C. Cost of Execution	AC	B3	x	D4	E3	F2
D. Environmental Loading	D4	BD	D4	x	DE	D2
E. Life Span - Maintenance	E3	B4	E3	DE	x	EF
F.Physiological Effect of Construction	A2	BF	F2	D2	EF	x
	A	B	C	D	E	F
Raw Score	3	11	1	12	8	2
Weight of Importance (0-10)	3	9	1	10	6	2

5	Excellent
4	Very Good
3	Good
2	Fair
1	Poor

Alternatives							Total:
1. Wood Frame Construction	4	2	3	4	1	5	89
2. Steel Frame Construction	1	4	1	1	2	4	70
3. Aluminum Frame Construction	1	3	1	1	3	2	63
4. Reinforced Concrete Frame Construction	3	4	2	2	4	1	93
5. Traditional Brick wall	3	4	5	3	4	5	102

Table 2: The Application of Criteria Matrix With Keeping the Environmental Consideration in View

3. THE BUILDING PATHOLOGY IN THE PROCESS OF BUILDING MAINTENANCE

The landmark of the building maintenance is the determination of the optimal life span of the building. It is a severe task in case of a complex structure, since the application of more constructions together results countless structural solutions and enormous number of joint formations. Beside this, the behavior of constructions of heterogeneous materials that is evoked by the external effects (the number of them and their variation is also high) alters. In the best case the constructions become unsuitable in the building simply as a consequence of their age. Reality is that these occurrences – in many situations the lack of building maintenance leads to here – are not frequent. In the major cases expert may discover failures, which endanger other constructions.

3.1. The Systematization Of Effects

The large number of diagnostic tests draws one's attention to several connections. Basing on them, the causes of defects of certain construction can be arranged into groups [5]. Analyzing more profound relations the knowledge of effects and interactions is a serious help.

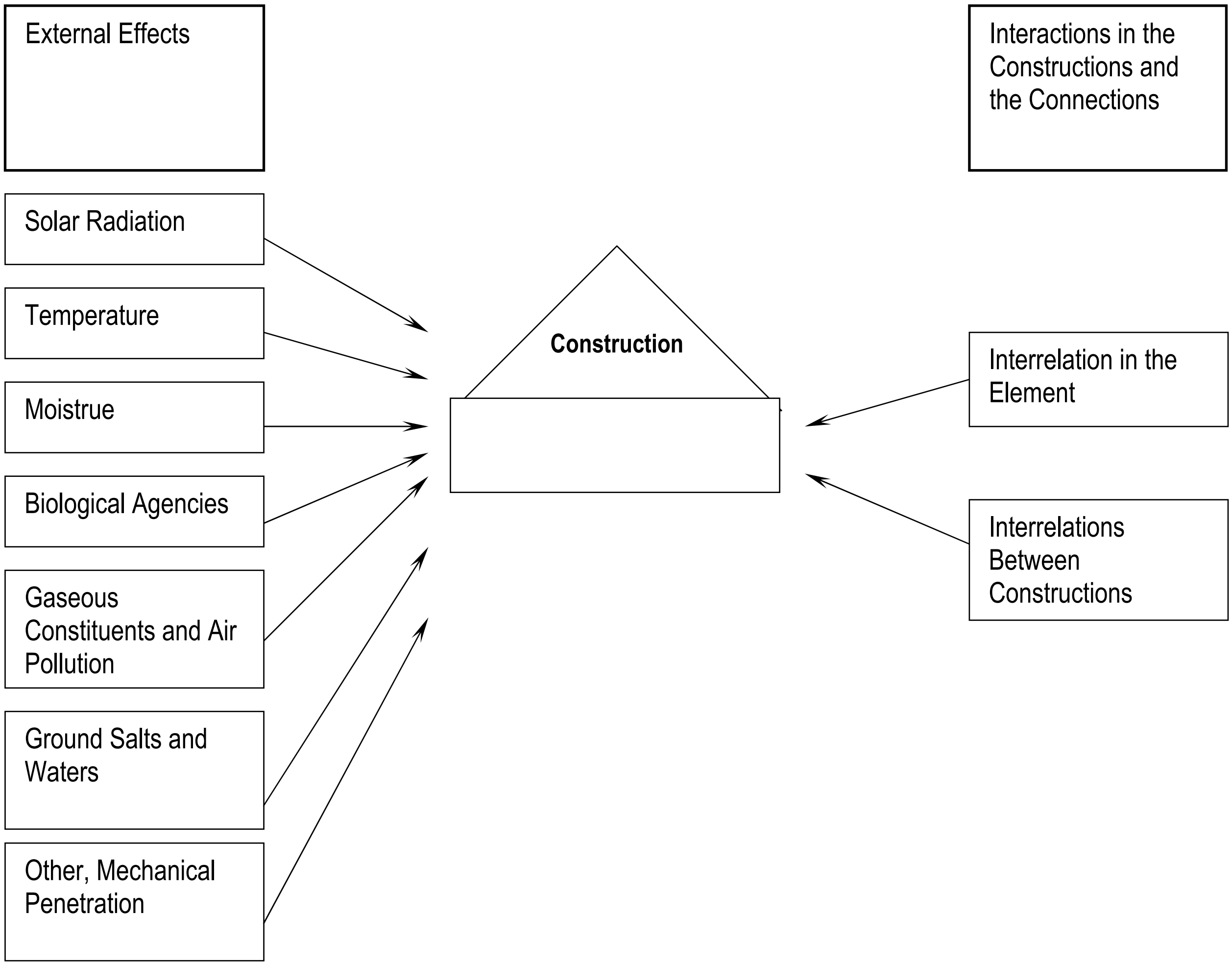

Figure 5: The Effects and Interrelations of Constructions and Their Materials

The external effects and the deterioration of the materials of constructions can be shown easily in a table (Table 3.). The table below is not complete, only the most common materials and the sources of their failures are named. Because of the vast number of plastics used in buildings they take a part here only with their common properties. For the sake of avoidance and reducing failures the designers and the executers have to focus on the proper choice of materials and the application of constructions. The outlook below may be a significant aid for its applicant. The adequate protection and choice of materials enlarge the life span (and thus the value) of the whole building. The right controls of building maintenance – with the knowledge of the effects and interrelations, as well as the knowledge of weak points of the materials of the constructions – may become more successful.

Materials \ Effects		Solar Radiation	Temperature Effects	Moisture	Frost	Biological Agencies		Gaseous Constituents And Pollutants Of Air										Ground Salts and Waters	Manufactured Products (chlorides)	Mineral Oil and Its Derivations	Sensibility To Other Materials
						Fungi	Insects	Sulphur Dioxide (SO_2)	Carbon Dioxide (CO_2)	Oxygen (O_2)	Ozone (O_3)	Nitrates (NO_2)	Soot	Unburned Fuel	Solvable Salts, Organic Acids	Sea Spray	Smokes				
Asbestos Cement						•			•												
Bitumen		•			•						•									•	
Concrete			•	•	•			•				•	•		•	•		•		•	
Reinforced c.			•	•	•			•	•			•	•		•	•		•	•	•	
Mortar					•			•					•	•			•				
Fired Clay					•										•	•					
Metals	Aluminum									•						•					•
	Copper							•		•					•		•		•		
	Lead														•						•
	Steel			•					•	•			•		•				•		
	Zinc							•							•	•					•
Glass			•																		
Plastics		•	•							•	•										•
Natural stone	Igneous																				
	Sedimentary				•			•					•	•	•	•		•			
	Metamorphic							•													
Timber		•		•		•	•														

Table 3: The Main materials of Building Constructions and the external effects

3.2. The Signs Of The Deteriorations Caused By External Effects

In the stressed cases below the missing or improper required repairs led to the present state, or the renovation is essential for avoiding the further deteriorations. The next details of buildings introduce in some fraction the slow ruin of our built environment

Figure 6: Wrong Draining System of The Balcony

Inaccurate External Drain System

The brick wall banister of the balcony of the building (Figure 6) – as it can be recognized from the signs – is damp. The degree of dampness is measurable from that some plants found the cracks in the mortar fine place for themselves. The solution of draining system is not only annoying from aesthetical view but it does not function correctly as well. The continuous wetting of the wall and the freezing of the water in the mortar endanger the strength of the construction.

Figure 7: The Frost of Cladding, Dampness

Fast Deterioration of the Brick Cladding

The harmonious appearance of the dwelling that alloys proportionally the marks of modern architecture is the designer's masterpiece. Getting closer to the building the failures of the façade are observable. The dampness and the brittles of the brick cladding can be traced back to the wrong execution of the concrete edge or the lack of sheet metal (Figure 7.). The vertical movement of water through the capillarity causes the wet cladding over the edge, the source of the brittle of brick is the rainwater coming down from the edge.

Spots on the Facades in the City

The Figure 8 shows a typical failure in the city where the traffic is high. the air pollutions deriving from the exhaust fumes gather in nodes on the surface of the newly plastered wall. These will not be the sources of further defects; they have just wrong visible effect. Beside the existence of air pollutions the cause can be the rough surface and the synthetic additives of plaster that attract the floating solid dust.

Figure 8: Plastered Façade in the Polluted Air

Stalactite Creation on the Lower Surface of a Stair in the Open Air

The stalactite creation is a typical failure of the reinforced concrete located in the open air [6]. During the chemical process in the reinforced concrete the water in the porous concrete becomes acidic because of the large quantity of carbon-dioxide that penetrates into the pores of concrete. The CO_2 dissolves physically, too, so called “aggressive carbonic acid” forms. That results the growth of depth of carbonation and the stalactites appear on the lower surface of the construction. The more important is that further failure is the decrease of the pH value of the concrete, which results the corrosion of the steel.

Figure 9: Stalactite Creation on the Reinforced Concrete

Failure of the Assembled Stone Cladding

A characteristic defect of the assembled cladding and its well visible cause can be seen on the Figure 10. In this case the corrosion of steel mandrel that holds the stone elements produces the failure. The separation of cladding makes the penetration of moisture into the construction easier that is why the corrosion of steel supplements accelerates, moreover, the building physical properties of the house weakens.

Figure 10: Separation of Stone Cladding

4. SUMMARY

After the general examination one must state that the evaluation of the building diagnostic analyses is barely partial; the possible combinations of effects and the selection of the constructions and their materials supports the wide range of variations.

The building pathologic studies that are fulfilled already – through the system of effects – may indeed contribute to the placing of building maintenance process on scientific basic. That is why one can state that the analyses may influence the life of the existing building parts and the constructions, which will be executed in the future indirectly. This can not be indifferent for the profession that adopts the ideas of sustainable development, since the prevention of artificial environment manipulates the health of our planet in the positive direction.

The statement that "We did not inherit the Earth, we just borrowed it from our descendants" is cited as the key phase of sustainable development. The sentence needs supplement for the experts, who maintain the build environment. The sentence sounds correctly: "We borrowed the Earth from our descendants, so we are the responsible to the buildings what we leave to them".

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