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# SELECTED PROBLEMS CONCERNING MAINTENANCE OF STRUCTURES

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**Abstract.** Many building elements, due to their destination, are exposed to the influence of external environment, often very aggressive. Due to that such building elements should be protected in a special way. I have presented the outline of problems related with maintenance of building structures, taking into account the principles of sustainable building. I have paid extra attention to the characteristics of local environment conditions and to their influence on the response of selected building elements. Building materials should be characterized with such features that will assure that the structures, in which they will be installed, will meet the requirements referring to service features. In this paper requirements regarding structural-material solutions for structures, bases for diagnostic tests and the essence of repair and rehabilitation of building structures has been discussed.

**Key words:** maintenance of building structures, sustainable building, sustainable development, thermal insulation protecting, durability, repair and rehabilitations methods

## INTRODUCTION

Many building elements, due to their destination, are exposed to the influence of external environment, often very aggressive. Due to that such building elements should be protected in a special way. The monograph [Czarnecki and Emmons 2002] is devoted to the issues of repairing and protecting concrete structures. The issues of repairing concrete structures in accordance with European standards were, among others, the subject of discussions during the conference "Jadwisin 2006" [Czarnecki and Łukowski 2006]. Because in excellent majority of cases we deal with structures made of concrete, the above mentioned publication may be useful for designing all sorts of repairs and reinforcements of the mentioned structures. Taking this all into account, I have prepared this paper in order to discuss more widely some issues, very important in my opinion. I have presented the outline of problems related with maintenance of building structures, tak-

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ing into account the principles of sustainable housing [Stawicka-Wałkowska 2001, Bryx 2003]. I have paid extra attention to the characteristics of local environment conditions and to their influence on the response of selected building elements [Starosolski 1976, Belok and Ślusarek 2003, Wilk 2004, Ślusarek and Wilk 2006, Wilk and Ślusarek 2006]. Requirements regarding structural-material solutions for structures, bases for diagnostic tests of and the essence of repair and strengthening of buildings structures were discussed as well.

## PRINCIPLES OF SUSTAINABLE BUILDING

Satisfying the needs of society is possible thanks to such shaping of buildings that makes them friendly for the users. At the same time, they must not interfere in surrounding natural environment in a considerable way and they must be acceptable from the point of view of incurred expenditures [Bryx 2003]. Such a point of view is in accordance with the principles of sustainable development, in particular with the principles of sustainable housing. Moreover, such principles should not only be valid during the process of erecting new building facilities, but also during the process of maintenance of existing structures [Bryx 2003]. It is with contentment that one may observe the fact that this sort of approach is favoured by the entries of chapter 6, entitled: "Maintenance of structures" of the act of 7.07.1994 – Building Engineering Law [Act of Building Engineering 2003].

The influence of building process on the environment begins on the moment of starting building works, and it ceases on the moment of dismantling of the facility and utilization of what is left of it. Such a process is commonly called technical life cycle of the structure and the assessment of the impact of this period of time on natural environment – Life Cycle Assessment [Stawicka-Wałkowska 2001]. In most cases the technical life-time run of construction of structure corresponds with durability and using period, justified technically and economically [Stawicka-Wałkowska 2001].

Each of the stages of technical life cycle of structure is accompanied by the use of raw materials such as water or energy mediums. This is why the method of operation and maintenance of structures is not neutral to the environment. Taking all that into consideration, the statement of the author of the paper [Stawicka-Wałkowska 2001] seems to be correct – the assessment of technical life cycle of building product or facility may be a criterion of its impact on natural environment [Stawicka-Wałkowska 2001]. Figure 1 presents the technical life cycle of building facility and product [Stawicka-Wałkowska 2001].

## CHARACTERISTICS OF ENVIRONMENT CONDITIONS

### Analysis of selected parameters of local climate

The term "climate" describes the average weather conditions resulting from observations carried out throughout tens of years, characteristic for the given area. As "weather" we understand a certain state of external atmosphere in the given moment, which determines the influence of meteorological factors occurring in the given place. The following are meteorological factors: solar radiation, air temperature, air pressure, air humidity,

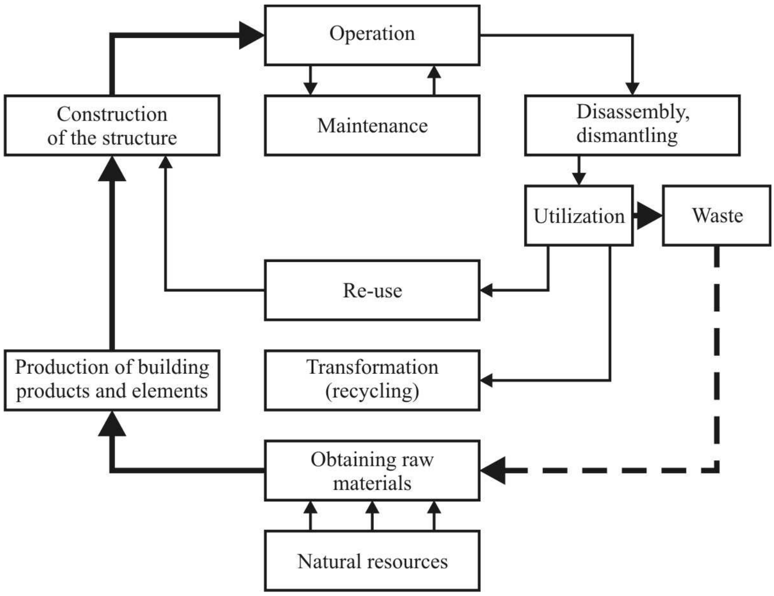


Fig. 1. Technical life cycle of building structure and product [Stawicka-Wałkowska 2001]
Rys. 1. Cykl życia technicznego obiektu i wyrobu budowlanego [Stawicka-Wałkowska 2001]

velocity and direction of wind as well as precipitations. The following are the factors describing climate: latitude, distribution of land and seas, height above sea level, sea currents and land shape. Furthermore, depending on the land shape, air pollution, amount of reaching solar radiation intensity, specific movements of air, we may distinguish local climate from the climate of the surrounding area [Basińska and Koczyk 1997, Basińska and Koczyk 2001, Kossecka et. al. 2001, Belok and Ślusarek 2003]. Therefore, local climate is an effect of greater or smaller influence of local factors [Rietschel 1972, Będkowski et al. 1975].

In this paper local climate is understood as conditions of weather state in the area of the test station. The pattern of chosen local climate parameters (total intensity of solar radiation and temperature of external air) has been elaborated basing on climatic date from the years 1994–2002 obtained in the laboratory of Ecological Building Division (Faculty of Civil Engineering-Silesian University of Technology) in Gliwice. The methods of creating and choosing the representative or typical meteorological year have been described in the papers [Basińska and Koczyk 1997, Basińska and Koczyk 2001, Kossecka et al. 2001]. Climate patterns for the city of Warsaw and Poznań have been elaborated.

In case of elaborating the pattern of local climate the measurement data of total solar radiation intensity projecting onto horizontal plane was available, as well as that of temperature of external air. Registering of the data was carried out continuously, once a half hour [Wilk and Ślusarek 2006].

Figures 2 and 3 present the obtained pattern of local climate in form of average year. Very important, from the point of view of analysed building elements, is the information that in the analysed average year there are 39 days of temperature lower than $t$ = 0°C [Wilk and Ślusarek 2006].

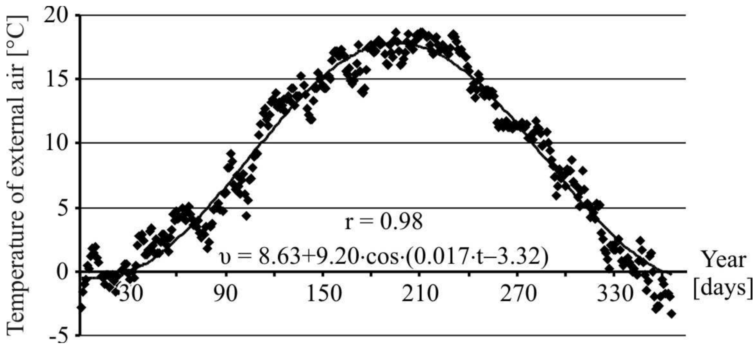


Fig. 2. Distribution of average temperatures of external air during a year [Wilk and Ślusarek 2006]

Rys. 2. Rozkład średnich temperatur powietrza zewnętrznego w ciągu roku [Wilk and Ślusarek 2006]

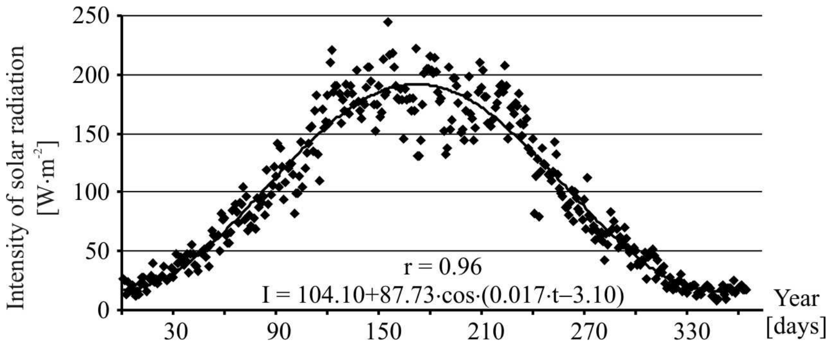


Fig. 3. Distribution of average values of total intensity of solar radiation during a year [Wilk and Ślusarek 2006]

Rys. 3. Rozkład średnich całkowitego natężenia promieniowania słonecznego w ciągu roku [Wilk and Ślusarek 2006]

## Solar temperature of external air

Solar temperature of air is defined as hypothetic temperature of air outside the building, at which penetration of heat through non-insolate partition would be the same as resulting from insolation with actual temperature of external air (fig. 4). Solar temperature of external air may be determined from the pattern [Pogorzelski 1976, Malicki 1977, Smolec 2000]:

$$t_s = t_z + \frac{AI_c}{\alpha_z} \tag{1}$$

where: $t_s$ – solar temperature of external air [°C],
$t_z$ – temperature of external air [°C],
$A$ – radiation absorption coefficient,
$I_c$ – intensity of total solar radiation [W·m$^{-2}$],
$\alpha_z$ – coefficient of heat transfer on the outside [W·m$^{-2}$·K].

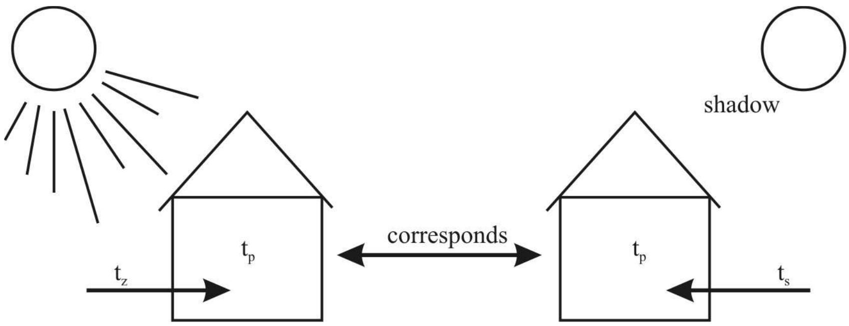


Fig. 4. Interpretation of solar temperature of external air: $t_p$ – temperature of air in the room, $t_z$ – temperature of external air, $t_s$ – solar temperature of external air (elaborated basing on Malicki [1977])

Rys. 4. Interpretacja słonecznej temperatury powietrza zewnętrznego: $t_p$ – temperatura powietrza w pomieszczeniu, $t_z$ – temperatura powietrza zewnętrznego, $t_s$ – temperatura słoneczna powietrza zewnętrznego (opracowanie na podstawie Malicki [1977]

In the paper the value of total solar radiation intensity projecting onto horizontal surface has been analysed, as well as the temperature of external air, observed in the years 1994–2002 in the laboratory (see above). From the data [Belok and Ślusarek 2003, Wilk 2004, Ślusarek and Wilk 2006] for appropriate seasons the highest and the lowest values for each of them has been selected. Figures 5–8 presents selected results of analyses of thermal influences in form of solar temperature of external air (compare with formula (1)) for the following values of absorption coefficient $A$ = 1.0 (mat black) and $A$ = 0.40 (polished aluminium sheet). The calculations have been also carried out for absorption coefficients of values [Malicki 1977]: $A$ = 0.50 (white colour), $A$ = 0.90 (bitumen paper), $A$ = 0.70 (galvanized metal sheet).

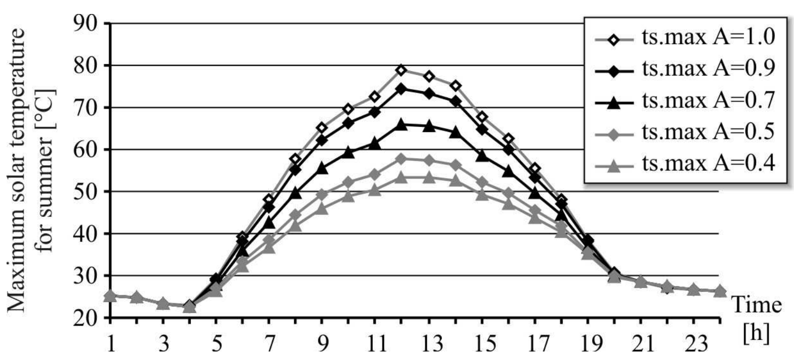


Fig. 5. Maximum values of solar temperature during summer period for different absorption coefficients [Wilk 2004]

Rys. 5. Maksymalne wartości temperatury słonecznej w okresie letnim dla poszczególnych współczynników absorpcji [Wilk 2004]

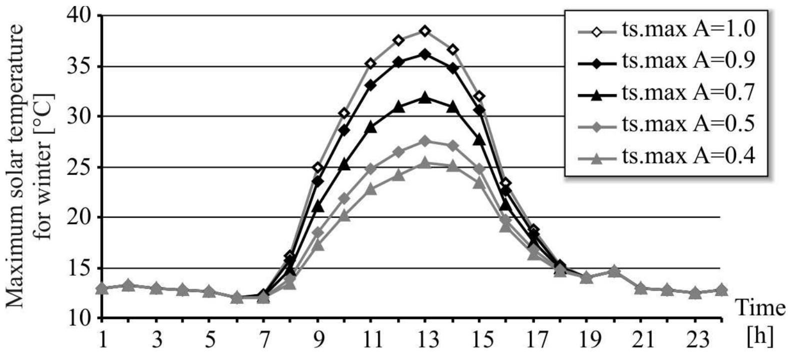


Fig. 6. Maximum values of solar temperature during winter period for different absorption coefficients [Wilk 2004]

Rys. 6. Maksymalne wartości temperatury słonecznej w okresie zimowym dla poszczególnych współczynników absorpcji [Wilk 2004]

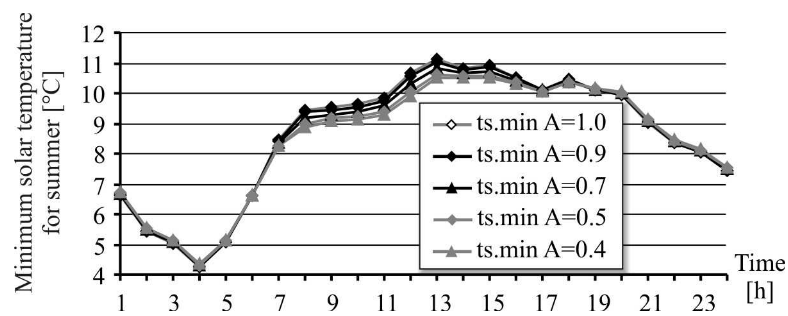


Fig. 7. Minimum values of solar temperature during summer period for different absorption coefficients [Wilk 2004]

Rys. 7. Minimalne wartości temperatury słonecznej w okresie letnim dla poszczególnych współczynników absorpcji [Wilk 2004]

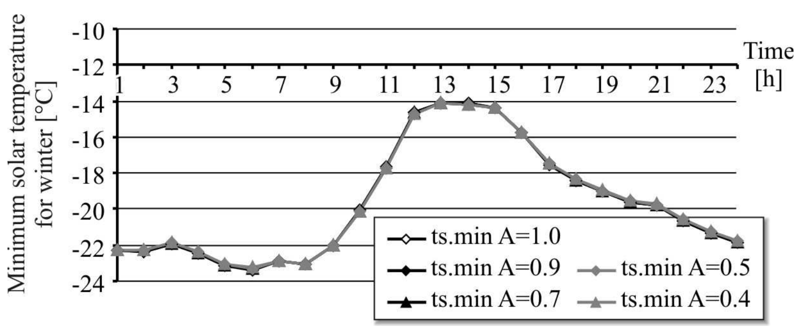


Fig. 8. Minimum values of solar temperature in winter period for different absorption coefficients [Wilk 2004]

Rys. 8. Minimalne wartości temperatury słonecznej w okresie zimowym dla poszczególnych współczynników absorpcji [Wilk 2004]

**Thermal stresses of structures**

Thermal influences on structures constitute a very important domain due to observed results, especially negative. Response of building in conditions of thermal load must be analysed in detail at the stage of design already. One should take into consideration the position of the building towards the sun, as well the possibility of protecting the building against excess insolation [Starosolski 1976, Ślusarek 1999]. Effects of thermal influences on building have been analysed on the example of a simple, but characteristic construction of flat roof (Fig. 9). Such solution has often been applied for a long time, which is confirmed with numerous examples of realization. Figure 14 presents schematic deformation of concrete roof tile and generation of thermal stresses forced in the building due to lack of appropriate circumference dilatations. Such influences result in damages, mainly of fire partitions. This can be described with the following relations:

$$R_t = h\alpha_T \Delta TE \cdot l$$
$$\sigma_{ST} = \frac{R_t}{al} = \frac{h}{a}\alpha_T \Delta TE \qquad (2)$$

where: $\alpha_T$ – coefficient of linear thermal expansion [°C$^{-1}$],
$\Delta T$ – difference of temperatures [°C],
$E$ – elasticity module of plate concrete [MPa],
$\sigma_{ST}$ – shearing stress in the wall [MPa],
$R_t$ – reaction of the wall to thermal influences [kN],
$h$ – thickness of roof plate [m].

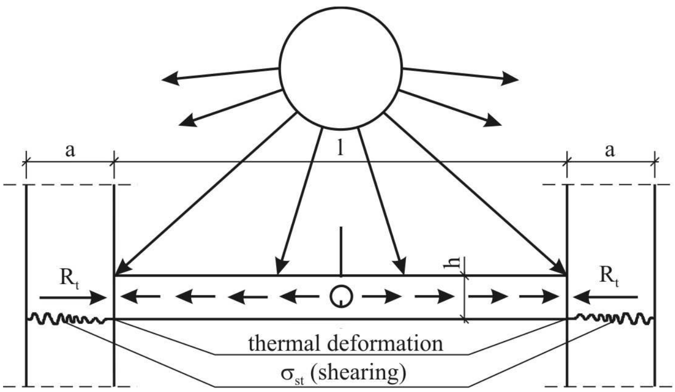


Fig. 9. Scheme of generating forced thermal stresses in the building (elaborated basing on Ślusarek [1999])
Rys. 9. Schemat generowania termicznych naprężeń wymuszonych w budowli (opracowanie na podstawie Ślusarek [1999])

Table 1 presents the values of shearing stresses in fire wall generated with thermal influences depending on the thickness of concrete plate and difference of temperature of concrete plate. Temperature differences refer to its variations as compared with the state in which the construction was unified.

Table 1. Values of shearing stresses in the wall (compare with Fig. 9)

| $\Delta T$ [°C] | Shearing stresses [MPa] in bricked fire wall of thickness $a$ = 25 cm* (Fig. 8) | | | | |
|---|---|---|---|---|---|
| | with the thickness of surface concrete layer [cm] | | | | |
| | 1 | 2 | 3 | 4 | 5 |
| 10 | 0.092 | 0.185 | 0.277 | 0.370 | 0.462 |
| 20 | 0.184 | 0.370 | 0.554 | 0.740 | 0.924 |
| 30 | 0.276 | 0.555 | 0.831 | 1.110 | 1.386 |
| 40 | 0.368 | 0.740 | 1.108 | 1.480 | 1.848 |
| 50 | 0.460 | 0.925 | 1.385 | 1.850 | 2.310 |

*Range of load capacity of the bricked wall (0.4 MPa) is above the thick line.

Basing on carried out tests, whose results are presented in Figures 5–8, it may be stated that thermal influences, especially reinforcing with effects of direct insolation, are considerable and require detailed analysis. The tests have revealed that the difference of temperature $\Delta T$ in plate of the analysed building (Fig. 9) may achieve considerable amounts. It has been shown that for the solar radiation absorption coefficient A = 1.0 $\Delta T$ may have values from 70°C in summer to even 30°C in winter. For solar radiation absorption coefficient $A$ = 0.4 analogous values of $\Delta T$ amount to 44°C and 15°C respectively. In the above analyses it has been assumed that the temperature of unifying the analysed construction amounts to $T_o$ = 10°C.

Analysis of diagrams presented in Figures 5–8 has also shown that $\Delta T$ may have negative values ($\Delta T$ amount to –13°C in spring to –33°C in winter). Those states are also unfavourable for the analysed building due to thermal contraction, mainly of concrete plate of balcony or terrace. Figure 10 presents examples of effects of thermal impacts on selected building elements.

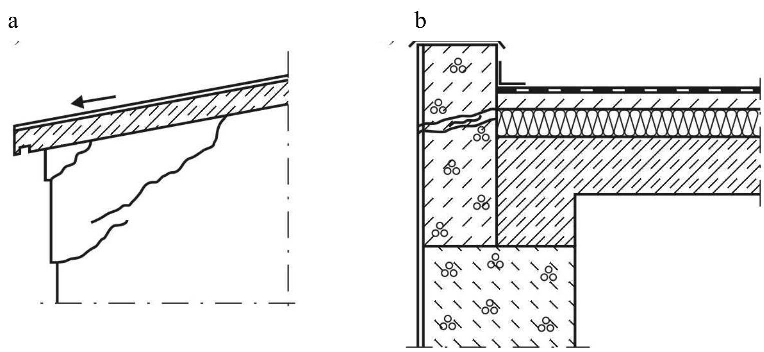


Fig. 10. Effects of thermal influences: a – breaking of corner due to lack of freedom of roof plate deformation, b – breaking of the bricked fire wall due to lack of circumference dilatation (elaborated basing on Płoński and Pogorzelski [1979])

Rys. 10. Efekty wpływów termicznych: a – pęknięcie narożnika na skutek braku swobody odkształceń płyty dachowej, b – pęknięcie murowanej ścianki ogniowej na skutek braku dylatacji obwodowej (opracowanie na podstawie Płoński and Pogorzelski [1979]

In the paper the results of testing solar temperature in test position in Gliwice is presented. The results of measurements and analyses have shown that even in our climatic conditions, the effects of solar radiation influence are considerable. It has been observed that the values of solar temperature for analysed conditions amount from 54°C to 79°C at about 1200, depending on the level of absorption of solar radiation by the materials of the structure of analysed building.

The effects of insolation of the building must be analysed in detail already at the stage of designing. It is very important to correctly shape building elements as well as their points of contact and connections, especially in conditions of intense insolation. Increases in temperature of construction parts by 44–70°C above the value of the temperature of their unification may generate forced thermal stresses of considerable values, often exceeding the load capacity of the construction.

**Selected methods of reduce results of thermal influences**

Results of thermal influences on buildings may be limited by applying appropriate dilatations. Separation of the building is caused with the necessity of limiting thermal dilatability influence on the construction. This type of dilatation does not comprise foundations, which, submerged in ground, are not subject to thermal influences. Figure 11 presents the scheme of building deformation resulting from temperature.

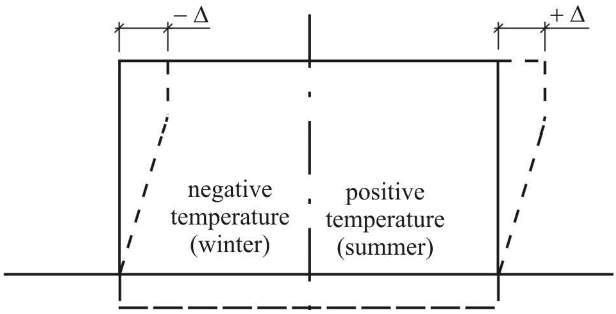


Fig. 11. Scheme of wall building deformation resulting from temperature (elaborated basing on Starosolski [1976])

Rys. 11. Schemat odkształcenia budynku ścianowego pod wpływem temperatury (opracowanie na podstawie Starosolski [1976])

Construction of flat roof is exposed to far greater changes in temperature than walls. Particularly strong thermal influences will influence the roof plate of ventilated flat roof, where, due to small heat capacity, it will not be the average daily temperature, but the average temperature of 1–2 hours will be decisive for the deformation. Hence the necessity of having dense enough dilatation of ventilated flat roof. The dilatation should reach deep inside the construction so as to provide free deformability of the plate (Fig. 12a). Execution of such construction is difficult, thus it is better to run horizontal dilatation of roof plate along longitudinal walls by laying the plates using dry method, using separator made of two layers of no-sand blast paper (Fig. 12b).

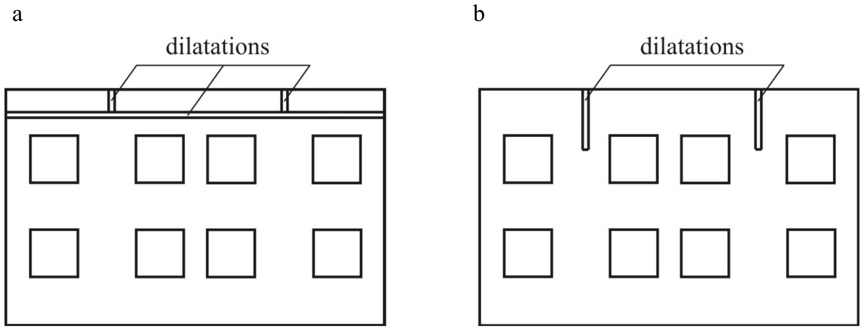


Fig. 12. Example of placing dilatations in a building with ventilated flat roof (elaborated basing on Starosolski [1976])

Rys. 12. Przykładowe rozmieszczenie dylatacji w budynku ze stropodachem wentylowanym (opracowanie na podstawie Starosolski [1976])

On the Figure 13 the method of dilatations distributing for roof plates of ventilated flat roof is presented.

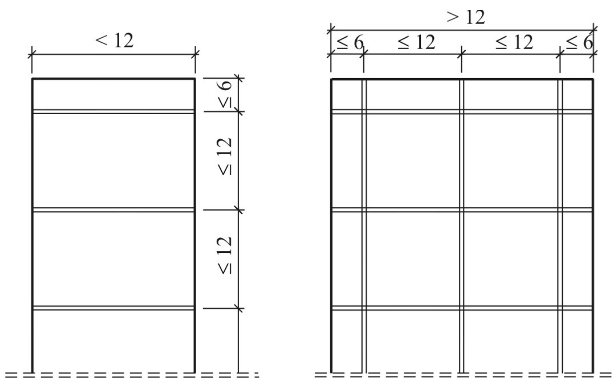


Fig. 13. Method of dilatations distributing of ventilated flat roof (elaborated basing on Starosolski [1976])

Rys. 13. Sposób rozmieszczenia dylatacji płyt stropodachu wentylowanego (opracowanie na podstawie Starosolski [1976])

Results of thermal influences on buildings may also be limited by using thermal insulation protecting against excessive warming of the structure. A good example of such solution may be green roofs, recently described in detail in the monograph [Ślusarek 2006]. An example of solution of such roof is presented in Figure 14.

## REQUIREMENTS REGARDING STRUCTURAL-MATERIAL SOLUTIONS FOR STRUCTURES

According to the European Union Directive [Directive of European Commonwealth Council 1988] building materials should be characterised with such features that will assure that the facilities, in which they will be installed, will meet the requirements referring

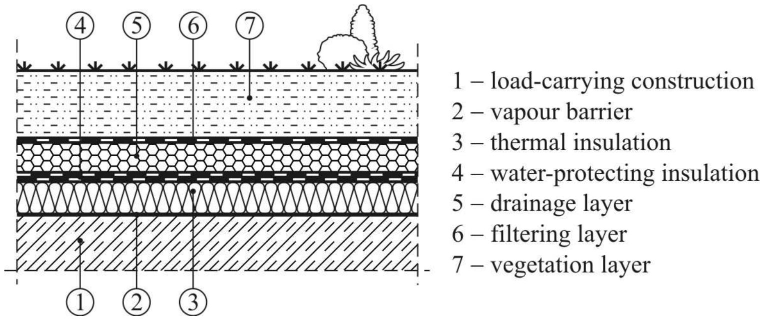


Fig. 14. Example of green roof solution (elaborated basing on Ślusarek [2006])
Rys. 14. Przykładowe rozwiązanie dachu zielonego (opracowanie na podstawie Ślusarek [2006])

to service features. The ability of the given material to meet the required functions during a determined period of time, in conditions of acting of determined factors, is called the durability.

The requirement of appropriate durability of structure is met if the construction fulfils its functions in terms of usability, load capacity and stability, during the whole planned period of using, without considerable decrease of its usability and with no excessive, unpredicted costs of maintenance [Czarnecki et. al. 1994, Ściślewski 1995, 1999, Fagerlund 1997, Ajdukiewicz and Mames 2004, Ślusarek 2006]. Usability features do not refer directly to materials. However, the materials should meet certain functions within the framework of the building facility.

The general requirements mentioned before are currently of key, pro-ecological importance. It may seem that these are experiences from recent years. Yet this is not the case. Vitruvius (note) already reached those conclusions in the 1st century B.C. His opinions in that domain is well illustrated by the scheme presenting the essence of designing, in the context of currently understood functions of engineer, architect and contractor, securing obtaining desired effects (firmitas, venustas, utilitas – Fig. 15).

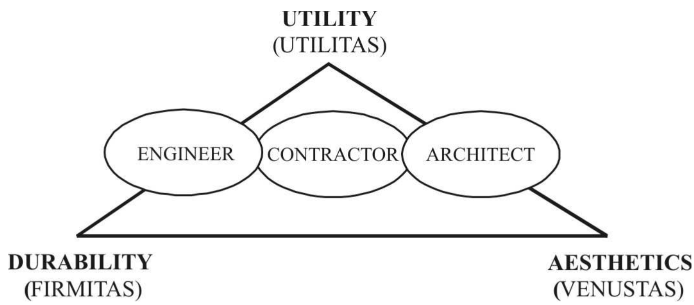


Fig. 15. The essence of designing building facilities according to Vitruvius (the drawing elaborated basing on Keller [1998])
Rys. 15. Istota projektowania obiektów budowlanych według Witruwiusza (rysunek opracowany na podstawie Keller [1998])

Taking the requirement of appropriate durability as the starting point, it seems that the essence of designing, presented in the scheme (Fig. 15) may be used for application during the process of shaping the structure of analysed building facilities.

## BASES FOR DIAGNOSTIC TESTS

Building materials, of which the building facilities are made, operate in complex conditions of various destructive impacts. Among them the key ones are mechanical, chemical, electrical, biological impacts as well as radiation [Święcki 1998]. Figure 16 [Święcki 1998] presents the scheme of destructive impacts. Destruction of materials may also occur as result of occurrence of numerous factors at the same time, which often causes the synergistic effect [Belok and Ślusarek 2003]. Single influences would not be enough to cause corrosion, and in total they cause quick destruction of the material, especially in moist environment [Czarnecki et al. 1994, Fagerlund 1997, Święcki 1998].

General principles of acting in assessing the condition of existing structures are presented in the standard [ISO/CD 13822]. The scheme of assessing the condition of exi-

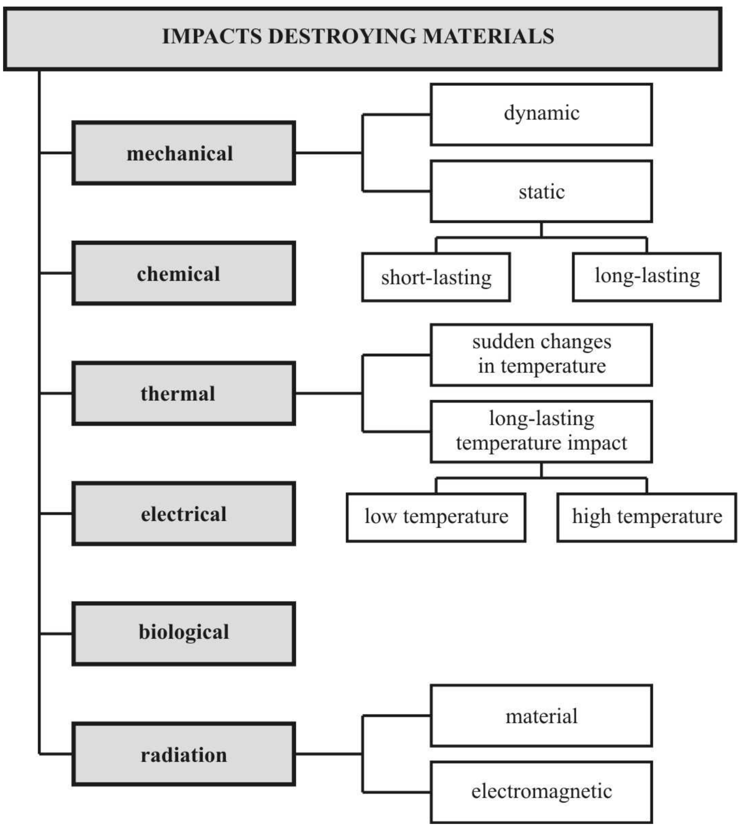


Fig. 16. Scheme of deterioration actions [Święcki 1998]
Rys. 16. Schemat oddziaływań niszczących [Święcki 1998]

sting constructions, elaborated basing on that standard, is presented in Figure 17 [ISO/CD 13822]. Detailed analysis of procedures included in this scheme allows for the conclusion that the general conditions of diagnosing building facilities, presented by me in the documents of WPPK Ustron 1999 [Ślusarek 1999], are not inconsistent compared with those. Therefore, those principles [Basińska and Koczyk 2001] may be useful as auxiliary material for expert – diagnostic specialist.

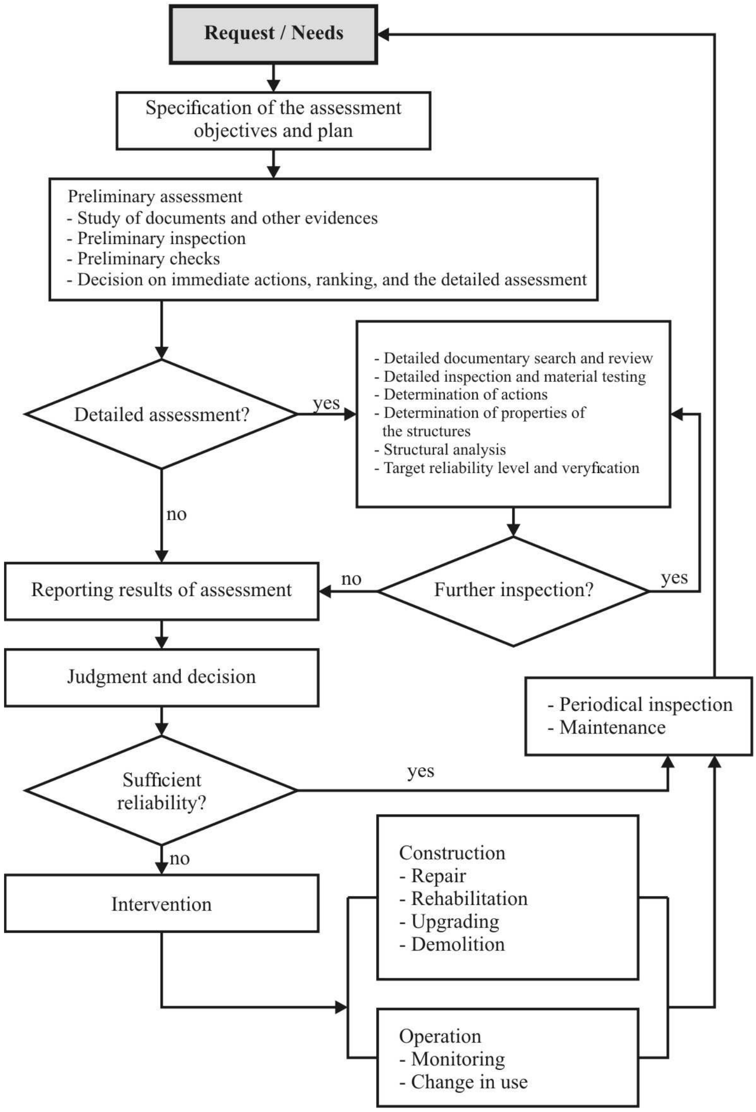


Fig. 17. Scheme of assessing the condition of existing structures (elaborated basing on ISO/CD 13822 standards [ISO/CD 13822])
Rys. 17. Schemat oceny stanu istniejących konstrukcji (opracowanie na podstawie normy ISO/CD 13822 [ISO/CD 13822])

Recently, a lot of attention is brought to the issues of durability of building structures. The analyses concerning the principles of service life design was recently presented by the author of the paper [Ajdukiewicz 2006]. Service life design is the assumed period during which the construction or its part is to be used in the planned way, with assumed scope of maintenance, but with no necessary repairs. The designed service life is determined by [Ajdukiewicz 2006]:

– defining appropriate limit condition,

– number of service years,

– level of reliability in relation to non-exceeding of the assumed limit condition in the assumed time period.

The design problems presented in the paper [Ajdukiewicz 2006] for the period of serv ice refer both to newly designed structures and to the assessment of existing structures – taking into particular consideration the remaining time of their service. This is a big challenge for Polish designers, as the author [Ajdukiewicz 2006] remarks. Required will be the analyses concerning the probability of destroying the structure in the context of their designed service time. Thus, it will be necessary to develop the concept of analyses of reliability and construction safety. These issues were presented for example in the paper [Murzewski 1970] – almost 40 years ago.

## THE ESSENCE OF REPAIR AND REINFORCEMENT OF BUILDING STRUCTURES

Repair of the building has the goal of complete or partial recovery of its service state, disturbed due to inappropriate execution or damage during operation. The following is distinguished according to EN 1504-3 standards [Czarnecki and Łukowski 2006]:

– non-construction repairs, not interfering with static operation of the building,

– construction repairs, comprising load-carrying elements of the structure, related with interfering with its static operation.

The following works connected with restoring the appropriate condition of the structure are distinguished in the paper [Czarnecki and Emmons 2002]:

– repair,

– reinforcement,

– stabilisation.

The repair, according to the author of the paper [Ajdukiewicz 2002] means restoring original load capacity of the structure. The reinforcement means increasing the load capacity of the facility above the designed state. The stabilisation is understood as a set of actions aiming at stopping the development of undesired situation [Czarnecki and Emmons 2002].

On the Figures 18–24 example methods of repair and temporary protections of "old" Cathedral Sanctuary of God's Mother from Guadalupe in Mexico City are presented [by author].

Reinforcement may be passive or active. Passive reinforcement takes place when used material fills the planned space, though it is not involved actively in the cooperation. This also increases the load capacity or stiffness of reinforced element. The reinforced

Fig. 18. General view of "old" Cathedral in Mexico City (photo by author)
Rys. 18. Widok ogólny „starej" katedry w Meksyku (fot. autor)

Fig. 19. Trace of repair of facade masonry of "old" Cathedral (photo by author)
Rys. 19. Ślady napraw murów elewacji „starej" katedry (fot. autor)

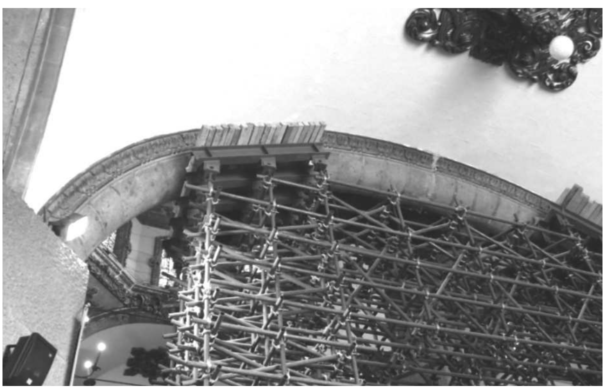

Fig. 20. Temporary protection of arch vault (photo by author)
Rys. 20. Doraźne zabezpieczenie sklepień łukowych (fot. autor)

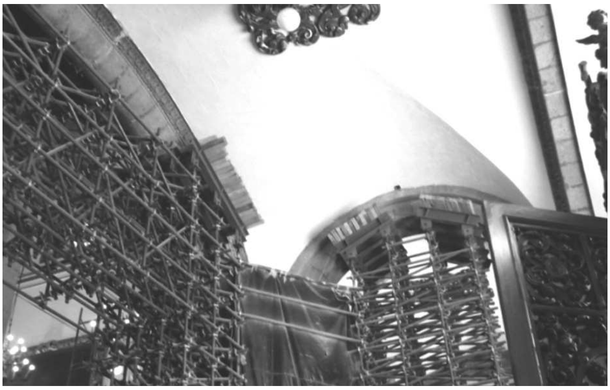

Fig. 21. Temporary protection of arch vault (photo by author)
Rys. 21. Doraźne zabezpieczenie sklepień łukowych (fot. autor)

Fig. 22. Steel ties-temporary protections of pillars (photo by author)
Rys. 22. Doraźne zabezpieczenie filarów za pomocą ściągów stalowych (fot. autor)

Fig. 23. Steel ties-temporary protections of pillars (photo by author)
Rys. 23. Doraźne zabezpieczenie filarów za pomocą ściągów stalowych (fot. autor)

Fig. 24. Steel ties-temporary protections of pillars – detail of pillar's head (photo by author)
Rys. 24. Doraźne zabezpieczenie filarów za pomocą ściągów stalowych – szczegół (fot. autor)

construction "waits" for the occurrence of forces from added loads [Ajdukiewicz 2002]. Reinforcing using active method consists in modifying static schema or introducing compressing forces to the structure. Active reinforcement "participates" in transmitting the loads "from the beginning" [Ajdukiewicz 2002].

The rule of compatibility, introduced during International Colloquium – Material Engineering and Restoration should be rigorously respected during repairs. This rule is described in detail in the paper [Czarnecki and Emmons 2002]. One should repair similar – similar both in material terms and in terms of technical features. "New" and "old" material should meet the requirements of compatibility in terms of [Czarnecki and Emmons 2002]: elasticity, creep, thermal dilatation and shrinkage during hardening process.

## NOTE

Vitruvius, 1st century B.C. – Roman architect and military engineer. In Octavian Augustus' service; the author of "Of Architecture" – the only preserved ancient treatise that had tremendous influence on the art of renaissance and on development of modern architecture theory [Popular Encyclopaedia PWN 1991].

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## WYBRANE PROBLEMY UTRZYMANIA OBIEKTÓW BUDOWLANYCH

**Streszczenie.** Wiele elementów budowlanych zgodnie z ich z przeznaczeniem jest narażonych na wpływy środowiska zewnętrznego, często bardzo agresywnego. W związku z tym każdy element budowlany powinien być odpowiednio zabezpieczony. W artykule przedstawiono zarys problemów związanych z utrzymaniem obiektów budowlanych z uwzględnieniem zasad zrównoważonego budownictwa. Szczególną uwagę zwrócono na charakterystykę lokalnych warunków środowiska oraz ich wpływu na zachowanie się wybranych elementów budowlanych. Materiały budowlane powinny charakteryzować się takimi właściwościami, aby obiekty budowlane, w które zostaną wbudowane, spełniały wymagania użytkowalności. W artykule przedstawiono wymagania w zakresie rozwiązań strukturalno-materiałowych obiektów budowlanych, podstawy ich diagnostyki oraz istotę naprawy i rehabilitacji obiektów budowlanych.

**Słowa kluczowe:** utrzymanie obiektów budowlanych, zrównoważone budownictwo, zrównoważony rozwój, zabezpieczenia termiczne, trwałość, metody naprawy i rehabilitacji

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