JCEEA

Czasopismo Inżynierii Lądowej, Środowiska i Architektury

Journal of Civil Engineering, Environment and Architecture

Kwartalnik
tom XXXVI
zeszyt 66 (nr 2/2019)
kwiecień-czerwiec

(e-ISSN 2300-8903)

Czasopismo Inżynierii Lądowej, Środowiska i Architektury jest kontynuacją
Zeszytów Naukowych Politechniki Rzeszowskiej - Budownictwo i Inżynieria Środowiska.

Issued with the consent of the Rector

Editor in Chief Publishing House of Rzeszow University of Technology
Professor Grzegorz OSTASZ, DSc, PhD

e-ISSN 2300-8903; p-ISSN 2300-5130

The electronic version of the Journal is an original version

Editorial Office: Rzeszow University of Technology, Faculty of Civil and Environmental Engineering and Architecture, St. Poznańska, 35-084 Rzeszów, Poland, www.oficyna.prz.edu.pl//pl/zeszyty-naukowe/czasopismo-inzynierii-ladowej-s/ (e-mail: jceea_bud@prz.edu.pl)

Publisher: Publishing House of Rzeszow University of Technology, 12 Powstanców Warszawy Ave., 35-959 Rzeszow, www.oficyna.prz.edu.pl (e-mail: oficyna@prz.edu.pl)

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JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 5-12, DOI:10.7862/rb.2019.7

Łukasz ŁUKASZEWSKI[1]

COMPARISON OF PHOTOGRAMMETRY AND LASER SCANNING METHODS ON THE CHOSEN ARCHITECTURAL OBJECT

Digitization of documentation of white cards is currently a key aspect of preservation of national heritage. Destructive processes of archival documentation, escalation of acts of vandalism, consequences of war operations that have left their stamp on architectural objects as well as monuments of nature contributed to adaptation and introduction of the fifth form of national heritage, which is "digitization". Digitization shall ensure the re-creation of not only lost national treasures in the future, but also shall enable researchers in architecture, archeologists, historians, conservators a research and an analysis of chosen objects and records related to it in a non-invasive and interactive way. Objects subject to digitization will be able to be analyzed more thoroughly since digital data rendered available by electronic means shall enable and facilitate an interdisciplinary research process. In the article, the author presents results that compare two methods for digitization of the chosen architectural object. Documentation consists in recording and preserving of the fragment of façade and the chosen architectural detail of the considered object. The object subject to analysis is the "Tenement under the singing frog" built in 1889–90 acc. to the project by Teodor Marian Talowski, in Kraków at Retoryki 1 St. For an analyzed example, research has consisted in application of photogrammetry and laser scanning methods to acquire information on spatial geometry of researched object and compare discrepancies of newly generated 3D models.

The object presented has undergone a comparative analysis, based on which the key aspects have been isolated and then demonstrated in a graphic way, as well as specific issues related to them, such as precision and effect of distortion have been discussed. The objective of the work has been presentation of possibilities of practical application of photogrammetry as a cheaper method of digitization of architectural objects in relation to scanning method, applicable in digitization and preservation of national heritage consisting in development of new interactive documentation (white card).

Keywords: digital image, inventory of monuments, digitization, white card, 3D documentation, discrepancy

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1. Introduction

Concepts of photogrammetry and laser scanning derive from surveying, where they are broadly applicable in documentation of shapes, dimension and space. *Photogrammetry is a field of science and technology, where researchers are engaged in re-creation of shapes, dimensions and relative position of objects in terrain based on photographic images* [1], out of which a point cloud is created. Laser scanning serves the purpose of determination of spatial position of vector elements, describing geometry of measured objects with radiometric sizes attributed to them. In this manner *"points of XYZ spatial coordinates, forming the so-called point cloud or triangular irregular net (TIN) describing the shape of measured surface"* are established [2].

Spatial measurement obtained from both methods may be used not only for saving of geometry of the registered object, but for acquisition of data and information of certain features of historical areas. Accuracy of performed measurements is dependent on conditions prevailing during measurements, properties of exact objects (complexity of structures etc.), and also on expectations of recipients of documentation-photogrammetry products [3].

Currently, while making measurements we are exercising guidelines of 1981, which require updating and adaptation to constantly developing technological possibilities, as well as new emerging market demands („*Wytyczne Techniczne G-3.4 pt.: „Inwentaryzacja zespołów urbanistycznych, zespołów zieleni i obiektów architektury*""[4]).

A continuous development of digital measurement techniques has created tools for reconstruction, reproduction and recreation of researched objects in a non-invasive way. Non-invasive process of digitization is a paramount quality of this method, allowing to protect [5] objects of national heritage. Thanks to establishment of the large database of objects, elements of cultural heritage can be protected in a new form from processes of biological destruction, lapse of time, consequences of warfare, as well as despoilment and devastation of property [6]. Therefore, preservation of national heritage properties is applicable in documentation, which is *sites and monuments record card called a "white card",* formulated in 1975 under the supervision of Prof. Wojciech Kalinowskiego. Apart from data included in a green card, it contains additional information. A well-prepared white card includes full, comprehensive information of the object adjusted to needs and scope of conservation measures. *Many most valuable objects have not been granted a white card until today, although it is regarded as a basic form of registration.* [7]

Therefore, diverse academic centers as well as scientific and research institutes [8] by using methods of digitization and computer-based technologies of varied degree of progression are making efforts to create new methodology of preservation of heritage (methodology of the "5th" generation) and creates „*digital white cards*" of objects.

2. Description of the research process

2.1. Methodology applied in the research process

The research process has been divided into two stages of work comprising the following activities:

a) Stage of field surveys:

- selection of surveying technology and deployment of the surveying scanner stations,
- doing surveys of characteristic façade elements by tachometric method,
- taking digital images of the building façade and the architectural detail from deployed stations.

b) Stage of inside works:

- calculation of coordinates of distinctive points on the façade of the building,
- recording and connecting of the scanner-acquired collection of points,
- creating a model in the form of mesh (TIN) of the building façade and architectural detail based on the collection of survey points from the surveying scanner. Points have been generated from photographic images by means of Agisoft Photo Scan software using distinctive points from tachometric surveying.

2.2. Characteristics of applied surveying instruments

For the research, the following instruments have been used for measurement of geometry of researched areas, based on which comparative models have been developed by means of specialist software.

The following equipment has been used for research:

- laser scanner – *Leica C10* impulse scanner,
- total station – *Leica MS50* – Surveying multi-station,
- camera – *Nicom D5000,*
- workstation *Fujitsu R920,*
- mobile workstation *XNOTE.*

Software used for data processing:

- *Cyclone 9.0* – software used for smoothing out of measurement data, generating orthophoto plans and coloring point clouds with digital images,
- *C-GEO* – software intended for calculation of the co-ordinates of points of reference based on tachymetry,
- *Agisoft Photo Scan Pro* – tool used to generate a collection of points based on photography,
- *Bentley Descartes V8i* – software for modeling based on TLS data
- *Geomagic Studio/ Control* – software developed for creating TIN model based on the collection of points, and for analyzing discrepancies in relation to the reference object.

3. Survey results of the chosen architectural objects

Results of surveys done using survey laser and impulse scanners as well as digital photogrammetry have been shown, applied for needs of comparative analysis of the fragment of the building façade, as well as the chosen architectural detail. The object considered is "Tenement under the singing frog" built in 1889-90, designed by Teodor Marian Talowski, situated in Kraków at Retoryki 1 St.

3.1. Analysis of the wall facade

Laser scanner and photogrammetry have been applied for comparative analysis of both methods in research using tachymetry of the fragment of the building façade.

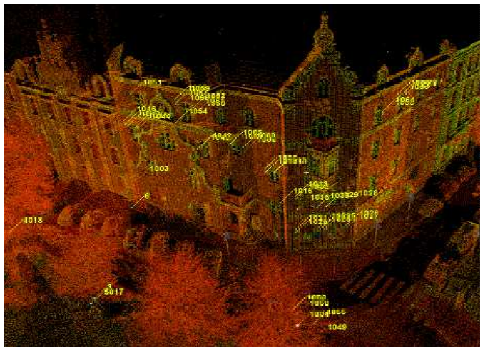

Fig. 1. Combined point cloud from a laser scanner, along with marked tachometric measurements

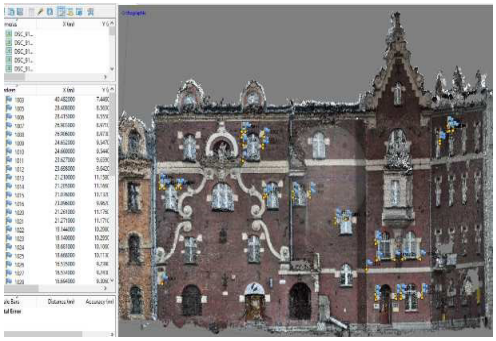

Fig. 2. Established photogrammetric point cloud with marked tachometric points

3.2. Analysis of architectural detail

Upon development of data from the total area of the object, the analysis of chosen architectural details has been conducted.

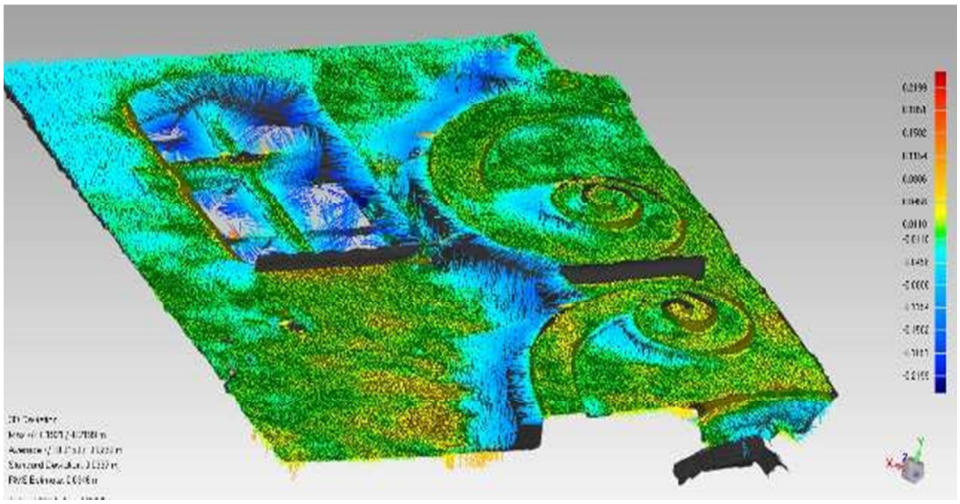

Fig. 3. Discrepancy analysis of architectural detail

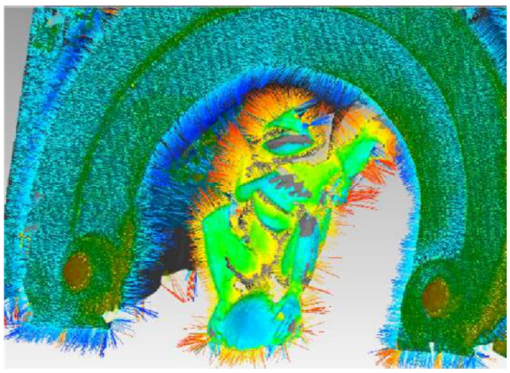

Fig. 4. The discrepancy of laser scanning and photogrammetry on the example of frog piece

Fig. 5. Model of architectural detail "Singing Frog" model TIN

4. Analysis of results

Based on conducted analysis, discrepancies in geometric parameters of obtained models can be presented in a graphic way. The model created from points acquired from laser scanner was used as a reference model. This model has been compared to photogrammetric model.

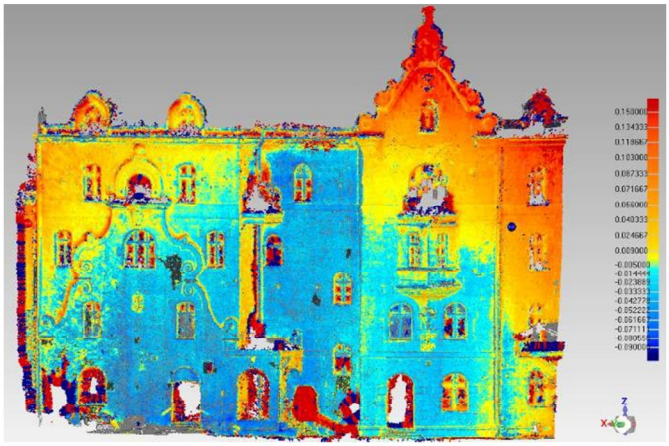

Fig. 6. A full analysis of discrepancies of laser scanning measurement in terms of photogrammetry on the example of the historic façade "Tenement under the singing frog"

Furthermore, results of comparative research by photogrammetric method with tachometric survey results as well as discrepancies in models obtained by these methods, have been presented.

Table 1. Table showing discrepancies of tachometric measurement of points in relation to points obtained by the photogrammetric method. A summary of the errors of each axis was presented as well as the number of overlapping images at reference points

Label	XY error (m)	Z error (m)	Error (m)	Projections	Error (pix)
1013	0.00845725	-0.0294726	0.0306621	48	2.507
1014	0.0177781	-0.0175875	0.0250076	47	2.984
1015	0.0133199	-0.00620727	0.0146953	46	2.137
1020	0.00917117	0.0200241	0.0220244	30	2.591
1021	0.0173721	0.014417	0.0225752	34	3.326
1022	0.0259006	0.0141942	0.0295349	31	2.265
1023	0.0271295	0.0203095	0.0338893	27	2.474
1024	0.0209427	0.0241801	0.0319887	26	2.043
1025	0.0260539	0.0145663	0.0298494	30	2.126
1026	0.0519761	0.008902	0.0527329	27	2.916
1027	0.0520016	0.0204739	0.0558869	25	3.249
1028	0.0388091	-0.00869272	0.0397707	39	3.966
1029	0.0226359	-0.00645667	0.0235388	36	2.078
1030	0.0171654	-0.00544268	0.0180076	43	2.740
1042	0.0429246	-0.0239622	0.04916	51	2.537
1043	0.0701864	-0.0156481	0.0719096	33	1.396
1044	0.0419124	0.00113345	0.0419277	34	1.839
1045	0.0343232	0.00247101	0.034412	34	2.120
1046	0.0599911	-0.01125	0.0610368	30	3.990
1047	0.0517507	-0.00531357	0.0520227	32	3.505
1048	0.0652882	-0.000251203	0.0652887	32	2.767
1054	0.0127437	0.0117995	0.0173675	50	1.541
1056	0.0410553	-0.00257303	0.0411359	57	1.446
1057	0.0218688	0.0114438	0.024682	56	1.858
1058	0.0383336	-0.00628536	0.0388455	53	1.689
1059	0.0400231	0.00238785	0.0400943	51	2.067
1060	0.0132394	0.0122283	0.0180225	43	1.561
1061	0.0292655	0.000107204	0.0292657	43	1.612
1062	0.0124575	0.0191868	0.0228762	41	1.831
Total	**0.0363607**	**0.0165669**	**0.039957**		**2.448**

Accuracies of models developed by method of data obtained from scanning and digital images combined with tachometric surveys have been compared:

a) in case of use of digital images and surveys by total station, the model accuracy has totaled 4 cm,
b) an accuracy of the model developed from laser scanning data has totaled 0,4 cm [4 mm].

Discrepancies have been compared by means of verification of position of points on the example of TIN mesh (mesh surface) created out of data from scanning and model generated from digital images and on the example of two TIN meshes.

5. Conclusions

By summarizing results of the research using the laser scanner and photogrammetry, the following conclusions can be drawn:

1) Based on comparison of obtained results of the research it has been found that with an increased distance of researched element vertically, error of photogrammetric measurement increases to a greater extent. It is due to a phenomenon of distortion of mapped plane on a digital matrix. The biggest errors (in the order of 15cm) occur in the top part of the façade.
2) Measurement error between both methods is acceptable for this type of solutions and is included within the scope of 0,4 cm for laser scanning and up to 4 cm for photogrammetry. When preparing inventories, the method of laser scanning seems to be an optimal solution. In the event of necessity to contain details requiring higher precisions (e.g. window woodwork, architectural detail) in documentation, supplementing the measurement with additional tachometric observations shall be advisable.
3) Coloring of digital images reflects real colors more advantageously and projects the coloring of facades more accurately than laser surveying.
4) Use of laser scanning and photogrammetry is applicable e.g. in digitization of national heritage as recommendation for a "digital white card" of the monument.
5) Application of photogrammetric surveys for uncomplicated architectural objects is less costly, and obtained survey results are negligibly worse than results acquired from laser scanning.

Finally, I would like to extend my thanks to research team of surveyors from the University of Science and Technology in Kraków*, and in particular to: Dr Eng. Rafał Kocierz, Viola Margasińska, Miłosz Janda and Jan Mądrzyk*, with whom I have co-operated in conduction of this research. Without their assistance, this research would not be possible to carry out.

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Przesłano do redakcji: 23.05.2019 r.

CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 13-20, DOI:10.7862/rb.2019.8

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PRELIMINARY ASSESSMENT OF A FLAT ROOF RADIATION ON RADIATIVE HEAT GAINS OF NEARBY WINDOWS – A CASE STUDY

This paper presents the results of preliminary assessment of radiative heat flux received by selected windows from tar paper coated flat roof of the adjacent building. This study was conducted on an actual object: building "P" at the University of Technology in Rzeszow. Windows located on south-western elevation of "P" building are subjected to thermal and diffused solar radiation, coming from a flat roof of a nearby gym. It was suspected, that this extra heat flux may have significant influence on compartment overheating, that is observed by occupants of "P" building. For the purpose of this study, various atmospheric data, such as temperatures, solar irradiance and wind speed were collected on site. In order to gain more detailed insight into investigated problem, Finite Elements model of occurring phenomenon was developed. FE modelling along with calculations of necessary view factors were performed in Matlab 2019a. Our study demonstrated, that analysed windows receive twice the heat gains from the flat roof, that they would have received from grass covered ground surface in absence of the gym. It has been concluded, that the proximity of the flat roof with bituminous cover considerably influences radiative heat gains of the windows, especially these located at lower floors and the phenomenon seriously contributes to overheating of the compartments in studied building.

Keywords: thermal radiation, flat roof, view - factor, diffused radiation, radiative heat flux

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1. Introduction

New trends in building engineering observed for about twenty years, Focus on decreasing building Energy consumption and on introducing applications based on renewable Energy sources. One of possible solutions applied to cover building demand for heat and electricity are active and passive solar systems [1, 2]. Another solution for improving thermal balance of a building may be limiting overheating of transparent building barriers by using phase change materials [3, 4, 5].

Analyses conducted in [3–5] point out for a need for modifying insulated glass units in order to minimize diurnal temperature amplitudes of the glazing, which will result in improving thermal comfort of a room.

As it is described in [6, 7] thermal comfort of a compartment is strongly influenced by a shape of building's envelope, as well as by thermal and optical properties of its transparent building barriers.

An issue of overheating flat-roofed buildings is a subject of numerous research. It is concluded in [8], that excessive absorption of incident solar radiation by bituminous roofing may substantially increase Energy demands for air conditioning, most especially in urban areas.

Basing on the above literature review, it has been found purposeful to conduct preliminary assessment of radiative heat transfer between flat roof with bituminous coating and a nearby windows, to explain a potential cause of compartment overheating. The objective was accomplished by performing a case study. As the Object of the study, two windows in P building at Rzeszów University of Technology were selected. The elevation of P building that contains studied windows is adjacent to tar paper coated flat roof of a gym building.

Reliable modelling of a complex heat exchange between a flat roof and a nearby window requires to take into account a convective heat transfer.
This type of heat transfer between solid and a fluid may be described using Jacob equation [9].
Radiative heat transfer between two surfaces is realised by both thermal radiation, that is described by Stefan-Boltzmann law, and by reflecting and diffusing incident solar radiation.

2. Materials and Methods

2.1. Equipment

All the data necessary to perform our study were obtained using:

- Data logger COMET MS-6D MS6R,
- Data logger ALMEMO 2890-9,
- Temperature probe PT 1000,
- Energy meter FQA020 C,

- Pyranometer Almemo FLA 613 GS,
- Thermographic camera FLIR i7,
- Meteorological station GWS - 570,
- Laser rangefinder Leica Disto D2.

2.2. Research workstation description

Field research were conducted by two independent sets of measuring equipment.

The first set consisted of temperature probe with data logger, thermographic camera and laser rangefinder. These were used to measure flat roof temperature as well as the temperature of ground Surface in the immediate vicinity of the gym. Laser rangefinder was used to measure necessary distances and architectural dimensions.

The second set of apparatuses functioned simultaneously as a part of a permanent field workstation, located about fifty metres from the gym. There, external air temperature, total irradiance on vertical southward Surface and wind speed were measured. All the data were collected with one minute intervals. Figure 1 present a photography of mentioned flat roof.

Fig. 1. Photography of the gym's flat roof, that is adjacent to P building at Rzeszów University of Technology

2.3. Finite Elementsmodel parameters

It was expected, that due to its structure, upper Surface of analysed flat roof reaches thermal equilibrium very quickly in changing weather conditions, and functions in quasi-steady state in relatively short periods of time. To verify that assumption, a steady state FE model of the flat roof was developed, for further comparison with actual measurements.

The model was constructed in Matlab 2019a, applying Partial Differential Equations (PDE) thermal toolbox. We used triangular elements with six nodes each, and dimensions of the mesh were no larger than five millimetres. Structure of the flat roof's cross-section were learned from actual project of the building, and it was as follows:

- tar paper 5 mm,
- rockwool 250 mm,
- reinforced concrete 150 mm,
- cement plaster 20 mm.

It was assumed, that upper part of the gym has constant air temperature of 22°C throughout the year, while the Surface of tarpaper absorbs and emits heat as a grey body of absorptivity 0.93 and emissivity 0.92. It was also assumed, that external Surface of the flat roof loses heat by Convection according to equation [9].

$$q = \alpha \cdot \delta_T \tag{1}$$

where: $\alpha = 1/R_{se}$- onvection coefficient [$W/m^{2\cdot}K$];
δ_T - temperature difference between flat roof and ambient air [K];
R_{se}-external Surface heat resistance, based on wind speed [$m^{2\cdot}K/W$] [10].

2.4. Calculating the view factors

In order to determine how much of total radiant Energy emitted by the flat roof is actually received by a specified window, values of necessary view factors were calculated in Matlab 2019a using numerical integration tool.

It was accomplished using equation 2. presented by Pogorzelski in [9].

$$\varphi_{1-2} = \frac{1}{F_1}\int_{F_1}^{N}\int_{F_2}^{N}\frac{\cos\beta_1 \cos\beta_2}{\pi R^2}\,dF_1\,dF_2 \tag{2}$$

Equation Formula for view factor calculation

where: φ_{1-2} – view factor 1-2 i.e. fraction of total Energy radiated by Surface 1 received by Surface 2;
F_1 – area of heat radiating Surface;
F_2 – area of heat receiving Surface;
β_1, β_2 – are the angle between the surface normals and a ray between the two differential areas;
R – distance between surfaces F_1 and F_2.

3. Results

3.1. Geometry and view factors

Basing on manual measurements using laser rangefinder, the geometry of studied setting was established. The most important results are presented below:

Table 1. Geometry parameters of the site

Height of flat roof top	4.52 [m] above ground
Height of 1st floor window sill	4.73 [m] above ground
Height of 4th floor window sill	13.74 [m] above ground
Distance between centre of the flat roof and elevation of "P" building	6.12 [m]
Surface area of each window glazing	1.08 [m^2]
Surface area of the flat roof	216.24 [m^2]

Values of view factors were calculated for 1st and 4th floor windows for two cases:

- actual flat roof as the source of radiation;
- surface of the ground beneath the gym as comparative source of radiation.

Table 2 View factors calculated for four studied spatial settings

Setting	1st floor - ground	1st floor - flatroof	4th floor - ground	4th floor - flatroof
Viewfactor	$1.20 \cdot 10^{-3}$	$2.30 \cdot 10^{-3}$	$3.80 \cdot 10^{-4}$	$6.75 \cdot 10^{-4}$

For intended qualitative assessment, five sets of measured parameters were selected. These are presented in table 3 below:

Table 3. Measured parameters for five selected moments

No	Date and time	Solar irradiance on vertical surface [W/m^2]	Solar irradiance on horizontal surface [W/m^2]	Ambient (air) temperature [°C]	Temperature of the ground surface [°C]	Wind speed [m/s]	Temperature of the flat roof [°C]
		E_{90sol}	E_{0sol}	T_a	T_g	v_w	T_{fl}
1	2018-03-21 11:40	885.0	571.0	1.1	3.8	2.1	33.4
2	2018-03-23 16:00	481.0	521.0	13.6	8.0	1.5	47.3
3	2018-05-29 15:02	418.0	441.0	36.2	43.5	2.4	58.9
4	2018-06-13 10:30	192.0	217.0	25.1	17.5	1.2	40.2
5	2018-01-19 12:50	628.0	766.0	2.5	0.0	1.6	0.0

Basing on the data presented in Tables 1–3 incident radiative heat fluxes received by 1st and 4th floor windows were determined. It was assumed, that grass, snow and tar paper uniformly diffuse incident solar radiation.

Heat fluxes were calculated for windows located on 1st and 4th floor, for two settings presented in table 3. We analysed two alternative sources of radiative heat flux: an actual flat roof and a hypothetical, grass or snow covered ground if the gym was non-existent there

Table 4. Radiative heat fluxes received by the windows in selected conditions in presence or absence of the flat roof

No	1st floor - ground	1st floor - flat roof	4th floor - ground	4th floor - flat roof
1	123.65	250.76	39.13	73.62
2	125.35	293.86	39.67	86.27
3	173.92	333.25	55.04	97.84
4	116.72	259.64	36.94	76.23
5	263.84	505.69	83.50	148.46

It is to be noticed, that in both cases presence of the flat roof significantly increases total amount of radiant heat reaching surfaces of both windows. The mean ratio of flat roof's to ground radiation received by 1st floor window is 2.09 and 1.97 in case of 4th floor window.

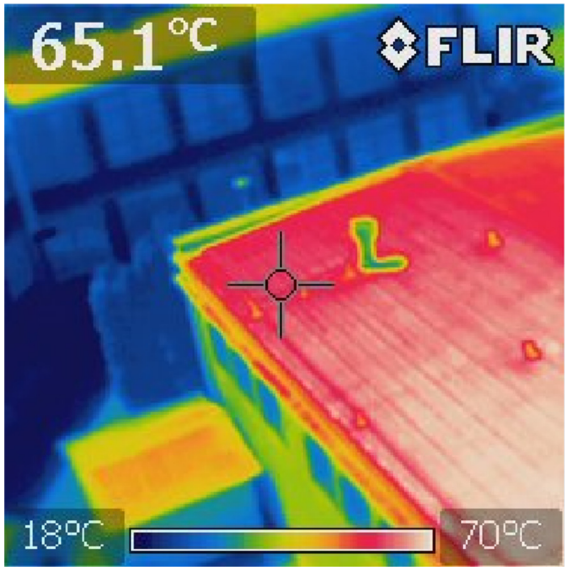

Fig. 2. Thermal image of sunlit flat roof of the gym adjacent to building „P" at Rzeszów University of Technology

3.2. Verification of FE model

Values of flat roof's temperatures obtained from our FE model were compared with actual field measurements. Our simulation was applied to conditions No. 1–4 only. Conditions No. 5 was not considered due to the presence of melting snow covering whole surface of the flat roof. Modelling the last example would have required application of transient thermal model with phase transition, which was not found necessary for this preliminary study.

Table 5. Comparison of actual and modelled temperatures of the flat roof's surface

No	Actual measurement [°C]	FE modeled[°C]
1	33,4	35,1
2	47,3	45,9
3	58,9	60,4
4	40,2	38,9
5	0,0	n/a

It is to be observed, that actual temperatures and these obtained from FE model does not differ more than ~2 K. Therefore, the model may be considered as satisfyingly accurate. Due to High emissivity of tar paper and considerable heat resistance of rock wool thermal insulation layer, upper portion of the flat roof has little thermal inertia and as expected reaches thermal equilibrium with its surrounding very quickly.

4. Conclusions

Performed study implies, that tar paper coated flat roofs may exert significant influence on heat gains of nearby transparent building barriers. In the studied case, presence of flat roof approximately doubled the amount of radiant heat received by windows located on both 1^{st} and 4^{th} floor. Due to increased distance to the source of radiation, slight attenuation of flat roof versus ground radiation was noticed for fourth floor in comparison with the first floor. If surface of flat roof is not covered by snow, its surface reaches much higher temperature than surface of the ground. The very surface of well insulated flat roofs with bituminous coatings operates in quasi-steady heat flow. In quickly hanging weather conditions such as variable illumination, temperature of these surfaces rapidly adapts to actual conditions and the surface reaches thermal equilibrium with its surrounding. This fact may be applied in further, more detailed studies of the subject e.g. in performing long term thermal balance of transparent building barriers, influenced by nearby flat roof's radiation.

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Przesłano do redakcji: 29.08.2019 r.

CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 21-34, DOI:10.7862/rb.2019.9

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USE OF QUANTITATIVE AND QUALITATIVE WASTEWATER MONITORING IN WATER PROTECTION ON THE EXAMPLE OF LODZ

Widely understood protection of water, and in particular surface waters, most exposed to direct pollution, requires many operations carried out both in the catchment area and in sewage systems as well as wastewater treatment plants. Due to its character and working conditions, it should be monitored not only in terms of hydraulics, but also in terms of the quality of transported wastewater. During atmospheric precipitation, large volumes of domestic and industrial wastewater as well as rainwater in various proportions flow through the canals, changing not only their quantity but also their composition. In such cases, the issue of monitoring becomes particularly vital. The article presents an analysis of the needs and tasks resulting from the application of quantitative and qualitative monitoring in the assessment of the functioning of sewage systems. Methods and tools used in Lodz that may be useful in water protection are presented. The benefits of using this type of solutions as well as the limitations and difficulties are discussed.

Keywords: sewer system, wastewater monitoring, rainfall monitoring, predictive model

1. Introduction

In recent decades surface water protection has become particularly essential among others due to the decreasing world drinking water resources and simultaneously the growing population and its requirements for water quality. Water protection largely depends on the functioning of sewage systems, which should not only ensure the safe functioning of the city, but also determine the ecological safety of the receiver. Urban development, and therefore an increase of urbanized areas in the total catchment area, additionally highlights the impact

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of sewerage systems on water reservoirs. In the last two decades, both methods and devices used for monitoring wastewater systems have significantly progressed [1, 2, 3, 4, 5]. It should be noted, however, that the functioning of sewage systems carried out wastewater from urban areas is associated with the occurrence and character of rainfall, which should therefore also be constantly monitored [6, 7]. In addition to changes in the character of precipitation as a consequence of climate variations, changes in air temperature are also observed. This affects in some way the temperature of rainwater directed to the sewage system and the temperature in the wastewater receivers. This may alter, among other things, the morphology of the receiver as well as the kinetics of the chemical reactions taking place in it.

Pollutants introduced by wastewater sewer systems largely affect the chemical and ecological state of reservoirs [8, 9, 10]. Monitoring of sewer systems should therefore be carried out in terms of both the quantity and composition of transported sewage [11]. This is particularly important for the assessment of pollution load in surface waters pollution load coming from the sewage system and wastewater treatment plant. Only comprehensive knowledge of pollutant emissions allows to fully control and effectively counteract the pollution of water receivers and promotes the proper functioning of the sewage system, even in conditions of variable flows caused by precipitation events.

Climate change and uncontrolled or poorly controlled growth of urbanization are also the main reasons of combined sewer overflows activation, which significantly affect surface water pollution [12, 13]. Therefore, it is important to know the frequency of their activation as well as the volume of wastewater and load of contaminants discharged by them into the aquatic environment. In pursuit of achieving good ecological status of waters, the impact on the receiver of agricultural and natural areas should also be taken into account. However, in urbanized areas, the impact of sewage systems is clearly dominant compared in comparison with other sources of pollution [14].

2. Analysis of needs, tasks and benefits resulting from the application of quantitative and qualitative monitoring

Urban development and the increasing incidence of extreme rainfall events leads to sewage systems, including wastewater treatment plants, being increasingly overloaded, which reduces their operational safety. The condition of optimal use of their technical capabilities and determining the necessary scope of modernization and expansion is knowledge of the hydraulic conditions of the network operation and the composition of flowing wastewater. The database required for this is facilitated by on-line devices. Until recently, on-line monitoring was most often carried out mainly in wastewater treatment plants to control treatment processes [15], and its use in sewage disposal systems was sporadic and rarely described [16].

Currently, on-line monitoring can be carried out using, among other things:
- rain gauges that allow determining rainfall characteristics,
- filling sensors and flow meters in channels,
- on-line sensors measuring one or several indicators of wastewater pollution simultaneously (multi-parameter sensors).

For effective control of the impact of wastewater sewer systems on receiver waters, it is important to define criteria for the selection of monitoring points [17]. Depending on the applied solutions a lot of information can be obtain, among others, for:
- recognition of the dynamics of flow variabilities in the sewers,
- composition of wastewater flowing through the sewage network both in dry and wet weather,
- monitoring of wastewater inflow to the treatment plant,
- calibration of computer programs used for network modeling,
- analysis of the "first flush" phenomenon of pollution in the sewage system,
- assessment of the functioning of sewage systems in the hydraulic aspect [18, 19], as well as pollutant emission [1],
- RTC system implementation (Real Time Control) in sewer networks [20].

In accordance with PN-EN 752: 2017 "External sewage systems", when conducting research and analyses relating to the functioning of sewage systems and determining the needs for their modernization, should be used simulation models that require accurate data from measurement campaigns. The use of on-line sensors measuring the concentrations of selected wastewater pollution indicators, especially in the case of combined sewer system, allows for a significant cost reduction of sampling, their transport and laboratory tests [21].

The use of quantitative and qualitative monitoring of wastewater sewer systems is extremely important for the functioning of wastewater treatment plants. Variations of quantity and composition of inflowing wastewater, sewer system modernization and changes within the catchment area may reflected in the inflow characteristic to the wastewater treatment plant and influence on hydraulic and pollution load.

3. Methods and tools used in Lodz

3.1. Characteristics of Lodz wastewater sewer system and the scope of its monitoring

Lodz is equipped with mixed sewer system. A combined sewer system (43 km^2) exist in the central districts and a separated system in the rest of the city. There are 18 combined sewer overflows, which discharge excess raw wastewater directly to Lodz rivers during heavy rainfall. The main receiver of all wastewater from the city, both the treated wastewater from the Lodz treatment plant and the raw wastewater coming from heavy rainfall, which is directed to

the receiver from combined sewer overflows is the Ner River. Currently, all overflows are equipped with flow meters, which allow to monitor the functioning of these facilities, determine the frequency of their activity and the volume of discharged wastewater (Fig. 1).

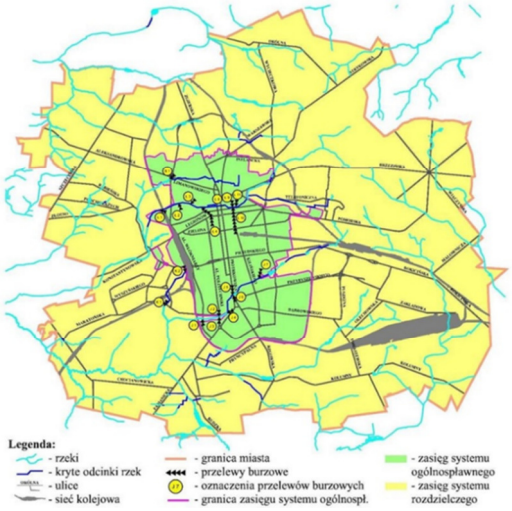


Fig. 1. Location of combined sewer overflows in Lodz [22]

In addition the measurements mentioned above carried out by the network operator, the monitoring of the sewer system in Lodz is also carried out by the Institute of Environmental Engineering and Building Installations at the Lodz University of Technology at two research stations:

- the station on the J1 overflow equipped with a flow meter and on-line sensors (Solitax and UVvis) for measuring the wastewater composition and a sampler for the automatic collection of wastewater samples,
- a station at the outlet from the stormwater drainage system of the "Liściasta" district with a rainwater settler, equipped at its inlet with a sampler for collecting wastewater, a wastewater fill sensor and flow velocity sensor in the sewer and at its outlet equipped with a sampler and a wastewater fill sensor in the settler.

3.2. Rainfall monitoring and its use

Lodz has an urban rain gauges network (18 devices) belonging to the Lodz Infrastructure Company. Additionally, three rain gauges belonging to the Lodz University of Technology and 12 rain gauges owned by the University of Lodz are located in the city (Fig. 2.). This type of data allows not only to determine the character of precipitation, but also to indicate the direction of precipitation and its spatial unevenness, which has a significant impact on the functioning of

the sewage system. Much more favorable for the operation of the sewer system is opposite direction of rainfall movement in relation to the direction of wastewater flow [7]. According to observations, during the year the air masses come to Lodz from the west (20% of observations), south-west (15%) and from the east (14%) [23], which in some way helps in removal of excess stormwater from the city area.

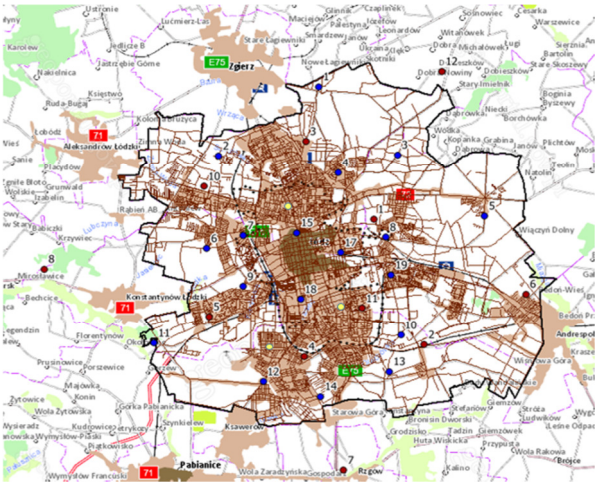


Fig. 2. Location of rain gauges in Lodz (blue - Lodz Infrastructure Company rain gauges, red - University of Lodz, yellow – Lodz Univarsity of Technology)

Currently, cities increasingly need to have digital models of sewer networks. Thanks to them it is possible to assess their functioning, as well as determine the needs for modernization and design guidelines. According to the current requirements contained in the Regulation of the Minister of the Environment (RME) of November 18, 2014 on the conditions which must be met during discharging wastewater into water or into the ground,, and on substances that are particularly harmful to the aquatic environment [24] to assess the functioning of sewer systems in the case of lack of data from observation of their functioning over longer period of time, it is recommended to use verified computer models. However, for these models to be useful and generate reliable results, it is required to correctly map the network and have accurate input data, including precipitation data, needed to calibrate the combined sewage and rainwater drainage network. Currently, many Polish cities do not yet have a pluviometric network, and have only, for example, one rain gauge (or only a few) for the entire city. In this case, it is difficult to determine the spatio-temporal characteristics of precipitation, which is especially important for large catchments area. That model calibration based only on one rain gauge usually causes overstatement of results [25]. Examples of the results of simulation flow rate in the sewage system in comparison with the actual rainfall data (spatial

precipitation, point precipitation) conducted in the use of the US EPA SWMM program at the outlet from the Bałutka catchment (609 ha) are shown in Figure 3. Results of the simulation of flow in the combined network for this catchment showed a better fit in the case of spatial precipitation, which confirms the usefulness of using extensive rainfall monitoring in the city.

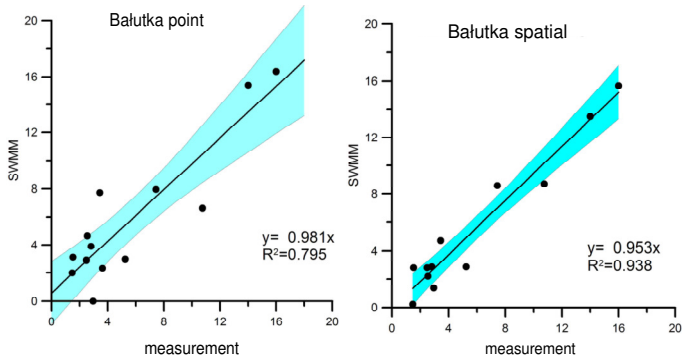
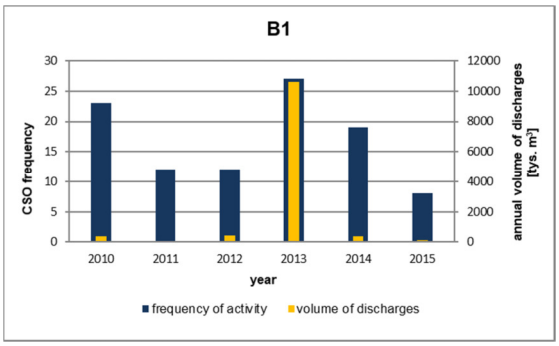


Fig. 3. Comparison of modeling results with real data of wastewater flow at the outlet of the Bałutka catchment area (flow stream in [m3/s]) [25]

3.3. Network flow monitoring.

In most major cities in Poland, combined sewer systems with overflows function in the central districts. Operation of these systems creates many problems, especially during the rainfall due to hydraulic overload of sewers and with the pollution load discharged to the receiver. The flow meters located in the area of combined sewer overflows in Lodz, allow to determine both the frequency of their activity and the volume of discharged wastewater, which is particularly important in the case of surface water protection. According to RME, the number of activations of these facilities should not exceed 10 per year. Therefore, quantitative monitoring allows to determine the correct operation of overflows or, if necessary, to indicate exceedances in their functioning (Fig. 4).
Based on the measured data, the frequency of combined sewer overflows (CSOs) can be analysed at various time intervals. In Lodz, most CSOs usually operate in the summer months, and the volume of discharged wastewater is greatly varied. In example the B1 overflow in both June and July, works on average around 3.5 times, but the volume of wastewater emitted to the receiver is several times higher in June. Without quantitative monitoring, obtaining such information would be very difficult.

a)



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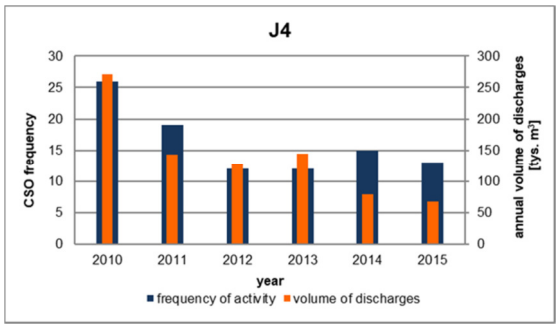

Fig. 4. Annual average frequency and volume of wastewater discharged by combined sewer overflow in the years 2010 - 2015, a) B1, b) J4 [26]

With this type of data, it is possible to determine the parameters relevant to the functioning of the network: flow variability (Fig. 5), hourly and daily unevenness coefficients, etc. The use of this data together with precipitation data in modeling systems enables their calibration (Fig. 6). This allows, among others, to identify overloads and establish the required storage capacity of the system and the possible channel retention capacity.

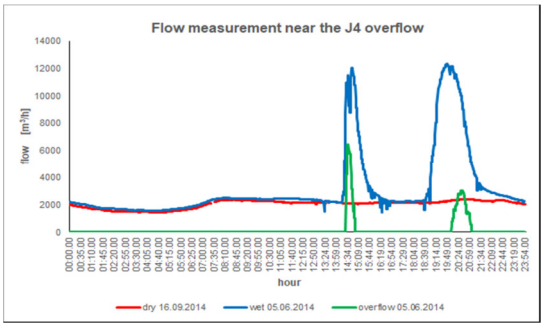

Fig. 5. Dynamics of flow variabilities during the day with dry and wet weather and an example of PB J4 functioning

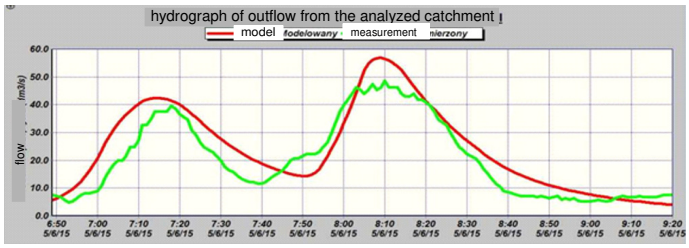

Fig. 6. The results of measurements and modeling of the intensity of rainwater runoff from the Liściesta catchment [27]

3.4. Qualitative monitoring of wastewater in the sewage system

During measurements of the first tested indicator a method of measuring UV absorption with a wavelength of 254 nm (according to DIN 38402 C2) is used, while the measurement of the second one is carried out in a combination of the absorption process and infrared rays dispersion (according to DIN 27027). The probes are calibrated using the results of laboratory tests on the composition of the wastewater collected with the sampler installed on the bench. The data obtained from the monitoring allow for the analysis of the concentrations of the measured indicators in dry and wet weather, as well as their changes depending on the day of the week, month, season, etc. (Fig. 7).

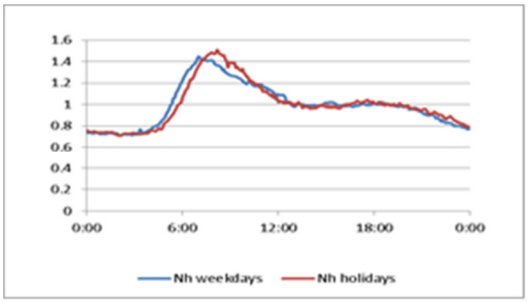

Fig. 7. Hourly unevenness coefficient for COD dissolved in dry weather [11]

Data from quantitative and qualitative suchej [13]monitoring allow to assess pollution loads transported through the network and their variability during rainfall events (e.g. occurrence of the "first flush" of pollution). For example, the J1 transfer on 27-28.04.2013 caused the discharge of 2598 m^3 of untreated wastewater transporting 992 kg of total suspended solids and 658 kg of organic substances expressed as COD. Data analysis obtained from qualitative monitoring confirmed the occurrence of the first flush phenomenon (Fig. 8), whose capture to the retention tank and subsequent referral to the wastewater treatment plant would significantly protect the receiver against the pollution inflow.

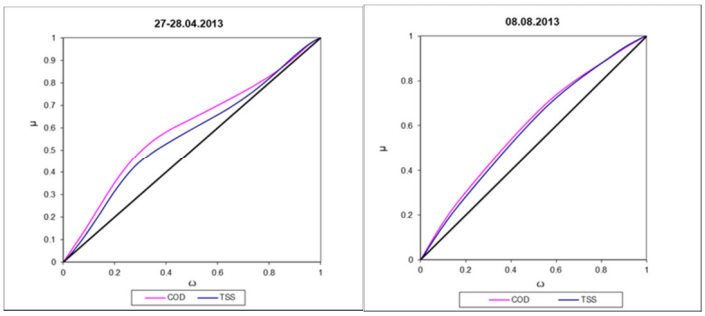

Fig. 8. An example of the occurrence of the first flush pollution phenomenon on the J1 overflow

The inflow of a large amount of pollutants in very short time, even if there are no toxic substances among them, can cause significant difficulties in the treatment process. Changes in the quality and quantity of sewage flowing into WWTP are not repeatable, they depend primarily on rainfall characteristic and the length of the dry weather period before precipitation, which determines the amount of pollution built-up on the catchment and wash-off during rainfall. Even on the same catchment, in the case of different precipitation, the first flush phenomenon may not be observed, it may be pronounced or the so-called the last wave phenomenon may occur, moreover, the flow of pollutants may be different for basic quality parameters of sewage (Fig. 5).

3.5. The use of monitoring data for pollutant load prediction

Continuous monitoring of CSOs and storm water drainage outlets is costly, labour-intensive and sometimes complicated for technical reasons. That is why simpler, less expensive, but equally accurate methods for estimating the quantity and composition of wastewater emitted to the receiver are increasingly being sought [2, 28, 29]. For this aim mathematical models are used, which allow to know and predict pollutant emissions and simultaneously limit the range of measurement campaigns. Based on the monitoring data, among others models for pollutant emissions from combined overflows and storm water drainage were developed for the Lodz catchment area. The predictive model of pollutant emissions from CSOs was based on three variables: height and maximum intensity of precipitation as well as volume of wastewater discharged from the overflow. These parameters were selected after a series of analyses using the PCA (Principal Component Analysis) method and multiple regression. On their basis, a mathematical formula to forecast the load of emitted pollutants for total suspended solids and COD was developed [30]. In addition to the parameters included in the model, other parameters such as the rainfall duration, its average intensity and the time of dry weather before precipitation were taken into account for the analysis. The results of the conducted analyses indicated that the

above-mentioned parameters turned out to be less important. In addition, Pearson correlations between rainfall parameters and concentration as well as the load of total suspended solids and COD were also made. The results showed practically no relationship between the concentration of the studied indicators and rainfall parameters, while strongly marked the dependence of the load on the height and maximum intensity of precipitation as well as volume of discharge, which was confirmed by the formula of the model.

$$L_{TSS} = 1.8 \cdot R_{depth}^{-0.37} \cdot i_{max}^{0.21} \cdot V_{CSO}^{0.97} \quad (1)$$

$$Ł_{ChZT} = 1.6 \cdot H_{op}^{-0.3} \cdot i_{max}^{0.22} \cdot V_{PB}^{0.95} \quad (2)$$

where: R_{depth} – rainfall height [mm];
i_{max} – maximum rainfall intensity [mm/h];
V_{CSO} – volume of discharged wastewater [m^3].

According to the developed model, the prediction of pollutant load emitted by a combined sewer overflow depends mainly on the volume of wastewater in power close to 1. It should be remembered that for a single CSO event, the volume of wastewater has a various importance relative to the load of emitted pollutants. This is due to the fact that precipitation parameters and the "first flush" phenomenon significantly influance the concentration of pollutants in surface runoff and CSO. The proposed model provides reliable results on pollutant emissions (R^2 = 0.79 for total suspended solids, and for COD R^2 = 0.80) in the case of the catchment area for which it was developed. For other catchments, this model can be used after adjusting the proporcional coefficient, which depends, among others, on the catchment characteristics, the way it is managed, sources of pollution, and the characteristics of the wastewater system and the overflow itself.

4. Advantages and disadvantages

On-line quantitative and qualitative monitoring used in sewage systems allows, among others, for:

- limitation of measurement campaigns,
- limitation of costs of wastewater laboratory tests,
- creating a large measurement database for analyzing of the functioning network,
- capturing all occurring variabilities of amount and composition of wastewater in both dry and wet weather.

These advantages are particularly important in the case of storm water drainage and combined sewer system due to the unpredictability of precipitation phenomena and high dynamics of changes in the composition of wastewater and

rainwater in these systems. The large advantage of using measurements directly in the medium is the high quality of the obtained data and the possibility of their transmission directly to e.g. a dispatcher, which allows making quick decisions regarding the operation of the system. It should be added that the simultaneous possession of rainfall monitoring gives the possibility of earlier network preparation and sewage treatment plant for sudden rainwater inflows. Despite the many benefits resulting form the use a such monitoring, some disadvantages should also be noted. Belong to them:

- still relatively high price, despite the dynamic development of measuring methods and technical solutions,
- sensors susceptibility to dirt, clogging and mechanical damage,
- lack of power supply or other factors preventing the measurement or causing erroneous data (e.g. indication of the instantaneous concentration value exceeding the repeatedly measured average minute concentration persistent for a very short time of the order of a minute or 2 minutes, most likely due to hanging up around the sensor of large things like rag, foil, etc),
- the need for periodic calibration for some types of equipment,
- in case of on-line sensors for measuring the pollution concentration indicators, limited range of indicators measured and the need to select it,
- location difficulties (e.g. lack of technical possibilities for mounting the sensor due to hydraulic conditions, no possibility of power supply, operational difficulties, difficulties with data transmission),
- difficulties associated with these installation (sewer condition, hydraulic conditions,sewer deposits),
- the need for periodic inspections and repairs.

Despite the possible operational problems and significant purchase costs, monitoring is already becoming the basis for suitable network management, especially in unforeseen situations, e.g. during heavy rainfalls. The benefits of having quantitative-qualitative monitoring (or even quantitative in the initial phase of its creation) are definitely higher than the potential disadvantages.

5. Conclusions

The examples of the on-line monitoring application included in the article have shown its great usefulness in determining rainfall characteristics, assessing of the wastewater sewer system functioning, and pollutant emissions directed to the receiver. On-line measurements allow to build a wide base for these purposes. The city's monitoring gives the possibility to observate changes taking place in the sewer system in real time and to reduce the costs associated with the wastewater analysis process. Despite the presented operational problems, having quantitative and qualitative monitoring is cost-effective and increasingly necessary due to the protection of surface waters. Sustainable development of city drainage systems will require the use of various forms of monitoring,

interrelated to one another (rainfalls, flows in the network as well as to wastewater composition).

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Przesłano do redakcji: 3.09.2019 r.

CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 35-47, DOI:10.7862/rb.2019.10

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COMPARISON OF METHODS OF TESTING RESISTANCE TO PERMANENT DEFORMATION OF MASTIC ASPHALT

The most common method to assess the resilience of mastic asphalt to permanent deformation is the static stamp indentation. The test is relatively simple and fast, but does not sufficiently differentiate of hard mixes. The paper presents a method to improve assess of asphalt concrete mixtures resistance on plastic deformations – indentation with dynamic stamp. The article describes the methodology of the test and interpretation of the results. Our study was performed on a mixture of mastic asphalt MA8 with the addition of natural asphalt TLA (Trinidad Lake Asphalt). The study achieved a sufficient correlation between the results of the static and dynamic test. It was also found that the dynamic indentation differentiates more detailed mixtures in terms of resistance to permanent deformation than static indentation test.

Keywords: static indentation pin, dynamic indentation pin, mastic asphalt, deformation

1. Introduction

Mastic asphalt is a bituminous mix with different properties from the commonly used asphalt concretes and SMA mixes. The high content of bitumen and filler makes the mixture self-compacting and waterproof. As a result, it is used for protective layers on bridges.

Analyzing the mastic asphalt requirements included in standard PN-EN 13108-6 [11], it can be concluded that this document specifies only a few mixture properties. In addition to the requirements concerning the quality of production and resistance to de-icing agents, fuel and abrasion by tires, only provisions regarding resistance to permanent deformation are marked. Test for resistance to permanent deformation can be performed under static or dynamic loading. In Polish requirements of WT2-2014 [13], static load indentation test was used to assess this property. They are made in a penetrometer that allows to

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apply an initial load of 25 N, then after 10 minutes an additional load of 500 N giving a final load of 525 N. It is transmitted through a cylindrical indentor pins with the area of 500 mm^2. During the test the sample is kept in a water bath at 40°C. The indentation after 30 minutes and the indentation increment after next 30 minutes are reported, each time as the average of two samples [9].

The test of penetration with the static load is easy and relatively quick, yet it does not sufficiently differentiate mastic asphalt mixtures, especially the harder ones [3]. In the penetration range of 1-3 mm, some mixtures, despite meeting the requirements, may have poor rutting resistance during operation [3]. For proper assessment of mixtures more test methods were developed. One of them is the dynamic indentation test. This method was developed in Germany. Based on the tests results, a good correlation was found between the results of laboratory tests and the depth of the rut in the pavement, as shown in Figure 1.

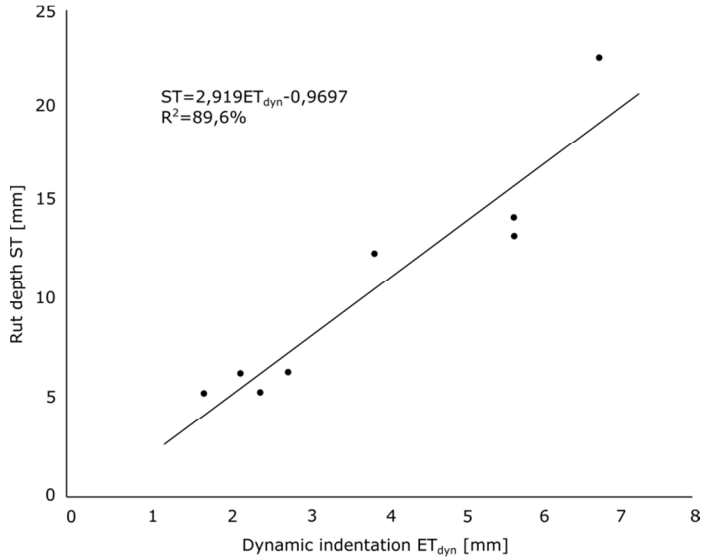

Fig. 1. Relationship between rut depth and dynamic indentation for bridge pavement for the various configurations of mastic asphalt type GA 0/11 [3]

Dynamic indentation test is performed in accordance with PN-EN 12697-25 method A [12], with minor modifications. Cylindrical samples 150 mm with diameter and 60 mm high are used for the test. The sample base planes are parallel to each other. The load is applied through a steel indentor pins with the area of 2500 mm^2 (diameter 56,4mm), cyclically with the following parameters [4, 6, 10, 12]:

- maximum load level: 0.875 kN (corresponds to the sample load 0.35 N/mm^2);
- minimum load level: 0.2 kN (corresponds to the sample load 0.08 N/mm^2);
- pulse duration: 0.2 s;

- rest period: 1.5 s;
- cycle time: 1.7 s;
- load curve shape: haversine.

The test is carried out in air conditions, maintaining a constant sample temperature of 50 ± 0.3°C. The shape of the load curve is shown in Figure 2.

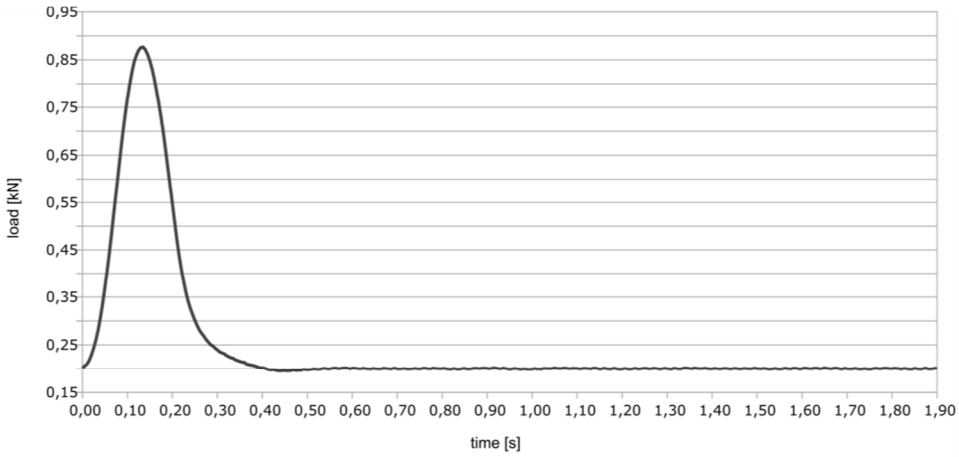

Fig. 2. Shape of the load curve in test of dynamic indentation

During the test, the change in height of the sample caused by the applied load is measured. As the result of the test, the indentation after 2500 and 5000 cycles is reported. The large sample diameter compared to the indentor pins diameter means that a steel mold is not needed for lateral restraint of the sample (as is the case with static indentation). At the same time, test conditions similar to real conditions are obtained, where horizontal deformation around the loaded place is reduced [3]. According to the standard [11], this test is recommended for mastic asphalt mixtures with mix size up to 11 mm and if the penetration under static load is less than 2.5 mm. Figure 3 shows an example of the test result. Line 1 is a mixture with good resistance to permanent deformation, while line 2 is a mixture with poor resistance. The similarity to the result of the rutting test is noteworthy, where at the beginning there is a large rut increase, followed by stabilization of this increase.

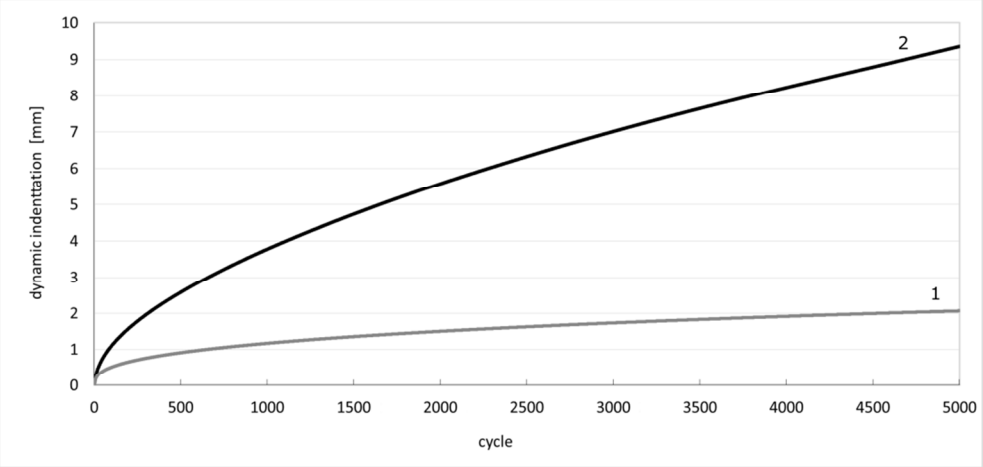

Fig. 3. Example of indentation curve in test of dynamic indentation stamp

Based on following experiments [3], it was found that mastic asphalts with penetration under dynamic load greater than 3 mm are not suitable for surfaces under high traffic loads. It was also noticed that mixtures with penetration at static load in the order of 1-1,5 mm have obtained dynamic test results in the wide range of 0,5-4,0 mm. Thus, doing the dynamic indentation test there is a possibility to reject incorrect mixtures. Moreover, there exists high sensitivity to changes in the composition of the mastic asphalt mixture, which allow to develop the most optimal mix formula.

2. Results

In the own research carried out under the grant[3] penetration markings of mastic asphalt with static and dynamic indentation were made. The MA8 mix with 35/50 road asphalt was used in an amount of 7 and 8 % m/m in relation to the asphalt mix and with the addition of natural asphalt Trinidad Lake Asphalt (TLA) in an amount of 0, 10 and 20% in relation to the weight of the pure bitumen. Table 1 presents the composition of the aggregate and bituminous mixtures. The mixtures were tested before and after simulated short term aging at 180 and 220 ^{o}C. The loose asphalt mix was laid out on a metal tray in a layer about 30 mm thick, and then placed in an oven with forced air circulation for 4 hours, with the mix being mingled every hour to ensure uniform aging conditions throughout its volume. The simulated aging temperatures were set at 180 and 220 ^{o}C as the delivery mix temperature at construction, including reduction of the base bitumen resulting from addition of the TLA.

[3] Umowa nr U-664-DS/M pt.: „*Ocena odporności mieszanek asfaltu lanego na deformacje trwałe w aspekcie starzenia krótko- i długoterminowego.*"

Table 1. Composition of the mixture of mastic asphalt

Content	Aggregate mix [%]	Asphalt mix A [%]	Asphalt mix B [%]
Bitumen 35/50	---	8.0	7.0
Filler	36.0	33.1	33.5
Basalt 0/2	32.0	29.4	29.8
Amphibolite 2/5	21.0	19.3	19.5
Amphibolite 5/8	11.0	10.1	10.2

Eighteen mix variants were tested, which allowed to obtain a wide range of static penetration. Figure 4 presents the designation of tested mix variants.

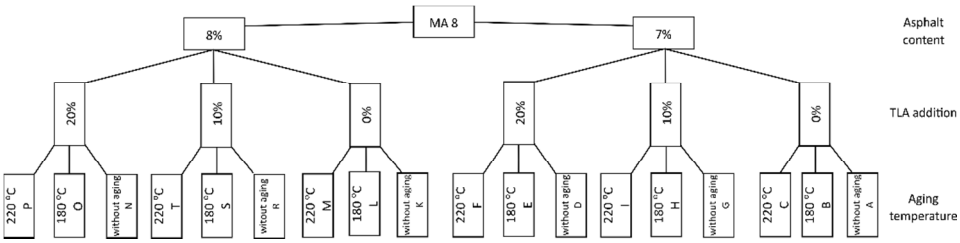

Fig. 4. Tests plan and sample symbols

The static indentation test was carried out in accordance with PN-EN 12697-20 [11] on cylindrical samples h <d formed at 220°C, while the dynamic indentation test was carried out in accordance with PN-EN 12697-25 [10], PN- EN 13108-20 [12] and information included in the articles [4, 6] on cylindrical samples with a diameter of 150 mm cut into slices about 60 mm high. A suitably adapted UTM-25 device was used for the tests. In the static test, the indentation was read after 30 and 60 minutes, while in the dynamic test the results were noted after 2500 and 5000 cycles. Before the dynamic test, the samples were thermostated for 4 hours at the test temperature and then subjected to an initial static load of 10 kPa. Figure 5 shows a sample with the indentor pins and measuring system installed. The indentation in the sample were obtained as the average of three values: two of the LVDT gauge based on a plate attached to the pins and one of the actuator displacement gauge. In addition to the method of applying the force and temperature of the test, the way the sample surface is prepared for testing is noteworthy. In the case of cubic or cylindrical samples for the static indentation test, the sample is not subjected to any treatment, therefore the coarse aggregate grains are submerged in asphalt mastic and do not have direct contact with the surface of the pins. However, in the case of the dynamic indentation, the surface of the sample is sanded with a saw when cutting the

sample into slices. This means that the loading punch has direct contact with the sawdust aggregate. In the case of a sample of uncut grains, the aggregates are point-loaded and can be "softly" shifted or pressed through a deepening punch. In the case of a dynamic indentation, aggregate grains are loaded on a larger surface, which means that they can be broken or tilted, sometimes increasing the contact area of the punch with the sample [1], as illustrated in Figure 6.

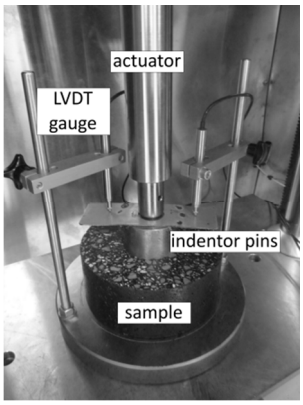

Fig. 5. View a set of measurement to study the dynamic indentation

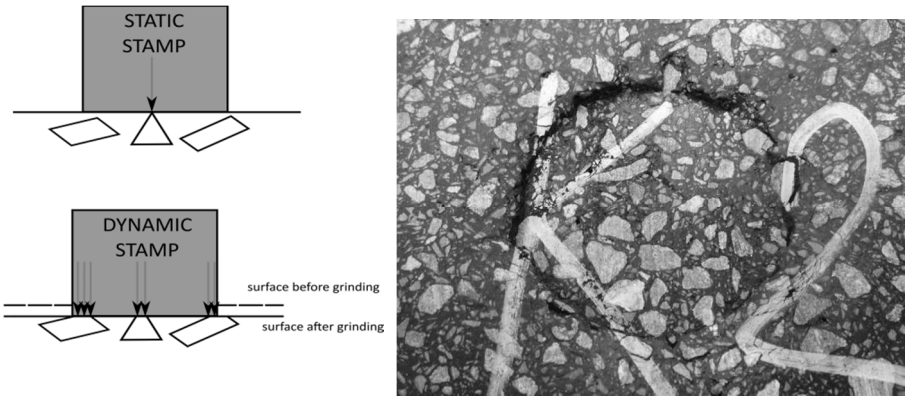

Fig. 6. Difference in samples of ground load and uncut and example spalling grains and thick on the surface of the sample after testing dynamic indentation

The obtained test results are presented in Table 2 and Figures 7, 8 and 9. Equations for calculating the results for both methods were also proposed. The quadratic equation for penetration has a better coefficient of determination than the linear equation. The static and dynamic indentation test results obtained were compared in the middle of the assumed test cycle and after the end of the cycle. Before calculating the regression curve, outgoing observations that could affect the regression curve were removed from the sample set based on the

values of studentized residuals. In this way, sample M was removed from further analyzis (marked as "outlier" in figures 7, 8 and 9). After its removal, no outliers were found in the sample set. A very good fit of the model to the calculation results was found for both curves. A Pearson r-correlation coefficient was calculated using a spreadsheet. For penetration after 2500 cycles, the result was $r_{2500} = 0.984$, while for penetration after 5000 cycles this factor is $r_{5000} = 0.987$. This means that there is a very strong relationship between the results of the penetration in the static test and the results in the dynamic test. Comparison of the results shows that the penetration values after 2500 and 5000 cycles are about 1,5 times higher than analogous in a static indentation test after 30 and 60 minutes, the penetration increases are about 3.8 times higher than in a static indentation test. The calculated r-Pearson correlation coefficient for the penetration increase is $r_{2500\text{-}5000} = 0.981$. Therefore, a very strong relationship between the results of these studies is observed.

Table 2. Results of the study of penetration stamp static and dynamic

Sample	Indentation [mm]				Indentation increment [mm]	
	30 min	60 min	2500 cyc.	5000 cyc.	Static	Dynamic
A	1.56	1.76	1.61	2.10	0.20	0.49
B	0.82	0.90	1.12	1.43	0.08	0.31
C	0.53	0.57	0.47	0.55	0.04	0.08
D	0.44	0.47	0.42	0.50	0.03	0.08
E	0.52	0.57	0.31	0.37	0.05	0.07
F	0.42	0.45	0.56	0.63	0.03	0.07
G	0.84	0.92	1.32	1.72	0.08	0.40
H	0.66	0.72	0.31	0.38	0.06	0.07
I	0.46	0.49	0.49	0.56	0.03	0.07
K	3.79	4.5	6.45	9.09	0.71	2.64
L	3.06	3.54	4.82	6.87	0.48	2.05
M	2.80	3.31	2.05	2.94	0.51	0.89
N	1.29	1.45	2.34	3.01	0.16	0.67
O	1.54	1.77	1.76	2.32	0.23	0.56
R	2.58	3.03	3.91	5.78	0.45	1.87
S	1.79	2.08	2.49	3.45	0.29	0.96
T	1.57	1.80	2.32	3.24	0.23	0.92

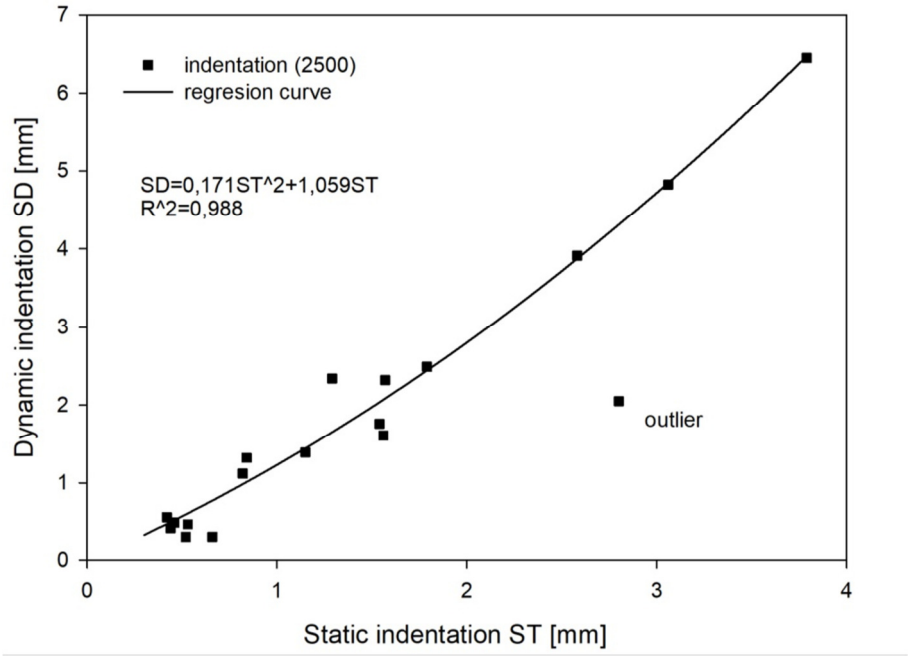

Fig. 7. Dependence of the penetration of the dynamic indentation of the static indentation for 2500 cycles

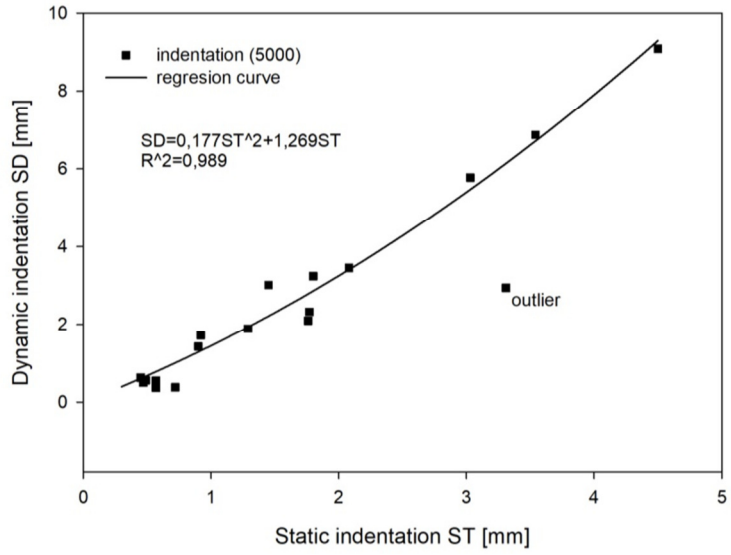

Fig. 8. Dependence of the penetration of the dynamic indentation of the static indentation for 5000 cycles

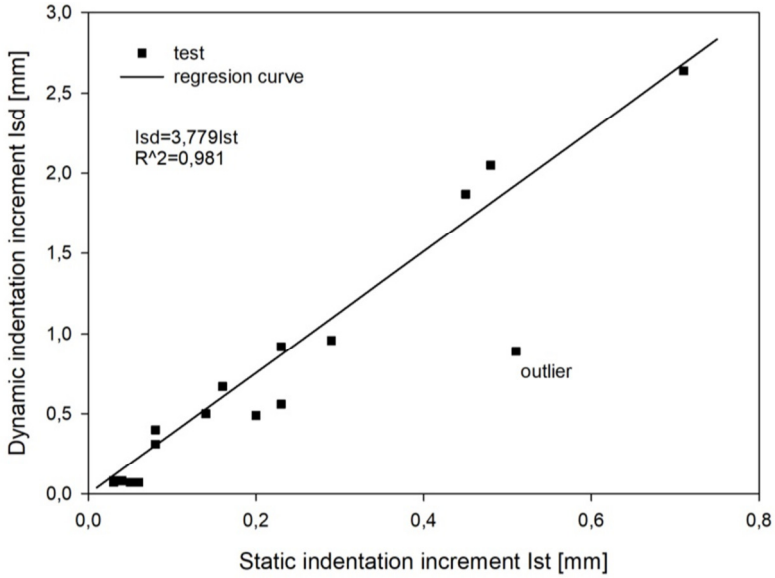

Fig. 9. Dependence of the dynamic indentation increment of the static indentation increment

Important parameter in the assessment of testing methods for resistance to permanent deformation is the measurement uncertainty. Due to the exploratory nature of the work associated with the use of dynamic indentation, it may give estimated values for the accuracy of the measurement method. For this purpose, the relative standard deviation was used RSD%. It was calculated as follow:

$$RSD\% = \frac{s}{x_{śr}} \times 100 \tag{1}$$

gdzie: $RSD\%$ – relative standard deviation, [%];
s – standard deviation;
$x_{śr}$ – mean value.

Result are shown in table 3.

Table 3. Relative standard deviation for samples tested

Sample	Mean [mm]		Standard deviation [mm]		Relative standard deviation RSD [%]	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
A	1.56	1.61	0.24	0.11	15.4	7.2
B	0.82	1.12	0.15	0.06	18.3	5.7
C	0.53	0.47	0.11	0.21	20.0	45.3
D	0.44	0.42	0.09	0.03	19.5	6.7
E	0.52	0.31	0.10	0.04	19.6	11.2
F	0.42	0.56	0.10	0.09	24.5	16.4
G	0.84	1.32	0.07	0.21	8.0	16.0
H	0.66	0.31	0.09	0.12	13.8	38.2
I	0.46	0.49	0.05	0.11	11.2	25.0
K	3.79	6.45	0.32	0.21	8.4	3.3
L	3.06	4.82	0.23	0.23	7.6	4.8
M	2.80	2.05	0.13	0.90	4.5	43.9
N	1.29	2.34	0.07	0.27	5.3	11.3
O	1.54	1.76	0.14	0.11	9.3	6.4
P	1.15	1.39	0.18	0.17	15.5	12.1
R	2.58	3.91	0.35	0.02	13.6	0.5
S	1.79	2.49	0.21	0.23	11.7	9.0
T	1.57	2.32	0.13	0.10	8.3	4.5

Presented data show greater accuracy of the dynamic method in the study of resistance to permanent deformation. In a few cases only, the coefficient of variation was greater than in the static method. The second research thread was to determine the effect of mastic asphalt composition on the sensitivity of the test method. The main assumption of this test was to check whether small differences in the penetration of the sample are caused by the way the sample was prepared (e.g., the way the aggregate was laid, the different degree of compaction) or it was only the effect of measurement inaccuracy. For this purpose, the one-way analysis of variance (ANOVA) test was used on 4 mixes with similar penetration values. Mixtures marked with letters: D, E, F and I were selected for comparison. Sample C was not included due to the high coefficient of variation. The static indentation values of these mixtures do not differ by more than 0.1 mm.

Table 4. Assessment of significance testing methods

Test method	SS	df	MS	F	p-value	Test F
Static	0.034953	3	0.011651	1.441	0.262	3.127
Dynamic	0.080233	3	0.026744	4.375	0.073	5.409

Symbols used in the table: SS – sum of squares; df – degree of freedom, MS – mean squared error; F – Fisher's statistic, p-value – the probability of obtaining test results at least as extreme as the results actually observed during the test, assuming that the null hypothesis is correct, Test F – critical F-value

Both analyzed methods do not statistically significantly differentiate the results of the penetration test at the confidence level $\alpha = 0.05$. Thus, it cannot be said unequivocally that it was the HMA composition that caused the difference in the indentation. It may as well be a measurement error or sample preparation method. Analyzis of the p-value draws attention to greater differentiation in the division of samples in the dynamic method (the p-value is slightly greater than 0,05), therefore it can be said that the dynamic method differentiates mixtures more than the static method. Also, the literature confirms the better usefulness of the dynamic method in the assessment of mastic asphalt, especially for mixtures with low penetration in the static test [3, 5]. It should be emphasized that the conclusions of the own research regarding the accuracy of the method ought to be confirmed by a larger number of samples tested. The static indentation test has already an established position in the Polish test methodology, which is why the requirements for mastic asphalt are confirmed in practice. Requirements for dynamic penetration adapted to Polish climatic conditions should be confirmed in practical applications. An example of foreign requirements that may be the starting point for creating Polish guidelines is presented in Table 5.

Table 5. Example foreign requirements for mastic asphalt tested dynamic method [5]

Category	Load due to		ET_{dyn} [mm]
	Traffic	Climate/Location	
1	Slowly rolling and standing heavy traffic (congestion range, slope/gradient)	Extremely warm summer, long direct insolation, mild winter	≤ 1.5
2	Rolling traffic with a high fraction of heavy traffi	Warm summer with direct insolation, mild winter	≤ 2.5
3	Rolling traffic with a low fraction of heavy traffic	Moderate temperatures, short insola-tion, cold winter, elevated location	≤ 5.0

3. Summary

Development of new research on the resistance of mastic asphalt mix is needed due to the insufficient methods currently used, especially for modern, hard mastic asphalt. The standardly used static penetration test does not sufficiently differentiate low penetration mixtures, only to a small extent enabling optimization of the MA composition. Modern test methods - penetration under dynamic load - give a greater opportunity for the most accurate selection of ingredients. The conducted own research confirmed that the presented method enables better differentiation of mixtures in terms of resistance to permanent deformations and HMA composition, than the static test.

4. Conclusions

- There is a need to find a better method for determining the resistance to permanent deformation of mastic asphalt. The current static penetration method used does not sufficiently differentiate mixtures in the penetration range of 1-3 mm.
- The dynamic method in mastic asphalt penetration testing is characterized by better testing precision.
- The dynamic method differentiates mixes to a greater extent, allowing the selection of the most optimal composition of mastic asphalt.

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Przesłano do redakcji: 5.09.2019 r.

CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 49-63, DOI:10.7862/rb.2019.11

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IMPORTANCE OF ARCHITECTURAL DESIGN OF HEALTH-AFFIRMING URBAN PLACES. ASSESSMENT OF THERAPEUTIC QUALITIES OF ZAC CLICHY-BATIGNOLLES IN PARIS

The presence of health – affirming everyday urban places is an invaluable asset for every neighborhood. The study presented encompassed the Post-Occupancy Evaluation of the therapeutic qualities of the urban tissue of certified eco-neighborhood in France. To perform this assessment the ready-to-use tool developed by the author, the universal pattern of design for health-affirming urban places was used. This study included the evaluation of the therapeutic qualities of Martin Luther public park located in the center of this neighborhood together with assessment of streets and paths leading to the park. The results were estimated as satisfactory. The architectural design of modern, human-oriented eco-neighborhood with centrally located public park lead to the creation of health-affirming urban place.

Keywords: therapeutic landscape, sustainable city, health and well-being, Universal Pattern of Design

1. Introduction

Numerous researchers from various fields, e.g. environmental psychology, medicine, sociology, architecture, and urban planning, have described the main qualities of therapeutic landscapes, which promote physical and mental restoration, encourage physical activity and social contacts [1,2,3]. The *Urban health-affirming landscapes* are everyday places that unite the qualities of *therapeutic landscapes* to influence people's physical, mental and spiritual healing [4]. Gesler [5,6] defined therapeutic landscapes as places where "*physical and built environments, social conditions and human perceptions combine to produce an atmosphere which is conducive to healing*". The ordinary urban spaces can promote the health and well-being of inhabitants. The presence

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of such spaces within city limits proved to be an invaluable asset. The research conducted by a team of Dutch researchers stresses the importance of green space close to home for children and lower socioeconomic groups as it is associated with lower disease and morbidity incidences [7,8]. The elderly citizens who enjoyed walking to green spaces were found to live longer [9].

The therapeutic landscapes are places that offer direct contact with nature. This phenomenon was explained by the biophilia hypothesis [10].

The design of health-affirming urban places is based on multiples theories developed by architects, physicians, psychologists and representatives of other Scientific fields. The purpose of this paper was to demonstrate how to evaluate the health-affirming potential of urban places. To perform the assessment a ready-to-use tool can be employed.

1.1. Methods

The universal pattern of design for health-affirming urban places is based on literature and field research which led to the development of the universal pattern for therapeutic parks [11, 12]. This pattern was expanded with the "access to park" category based on evidence which demonstrated that pleasant walkways to public parks are directly connected to increased frequency of visits to parks [13, 14].

In this study, it was used for the assessment of Martin Luther King Park and adjacent streets which are forming the core of the ZAC Clichy Batignolles neighborhood in Paris (fig. 1 and 2). This Park was chosen because it was developed on a brownfield, is relatively small – approx. 10 ha and surrounded by dense urban fabric. This study was undertaken also to verify whether it was possible to create health-affirming urban places in such a difficult urban location.

Fig. 1. Marked location of the EcoQuartier ZAC Clichy Batignolles in Paris cityscape. Source of satelite map: https://www.geoportail.gouv.fr/donnees/paris-haute-resolution, access: 30.11.2019

Fig. 2. Marked location of the park and EcoQuartier ZAC Clichy Batignolles. Source of satelite map: https://www.geoportail.gouv.fr/donnees/paris-haute-resolution, access: 30.11.2019

2. Assessment of therapeutic qualities of Martin Luther King Park and EcoQuartier Clichy-Batignolles in Paris

That neighborhood was designed by a team of François Grether - town planner, Jacqueline Osty - landscape architect and OGI engineers firm. This park spans over 10 ha. The Martin Luther King public park was designed to be a central point of a new district. The buildings were planned around it. This design scheme followed the Paris development strategy, which requires nature to become the city's structure element. An important task for the creators of the park was to create ecological corridors and develop the grid of green infrastructure. This park has no clear boundaries. It offers many different topics: - sport, water, etc. The planting was designed to remind people of the passing of seasons. [4, 15, 16, 17].

The evaluation of park therapeutic qualities was conducted using the universal pattern of design for health-affirming urban places (Table 1). Five visits to the park were necessary to verify the presence of the attributes, two of the visits were accomplished during events organized at the park. The assessment was performed for each of the attributes separately. The results of the rough binary assessment are presented in table 2. The results of the detailed evaluation are described below.

Additionally, a study of six streets leading to the park was performed. The results are presented in Table 3.

1. UNIVERSAL DESIGN

1.1. Place

The new neighborhood located in the center of Paris, France.

Area

The new Clichy-Batignolles neighborhood spans over 45 hectares and the Park covers 10 hectares.

The park has no clear boundaries. Park greenery sprawls into adjacent streets. Therefore, up to 10 ha of the park, you can add an additional 0.65 ha of green private areas inside the courtyards and 1.6 ha of green roofs of the eco-housing estate.

Location

This park is located in the center of a new eco-neighborhood - Clichy Batignolles in Paris.

Surrounding urban pattern

Dense urban tissue with mixed-use blocks (lots).

1.2. Environmental characteristics

Soil quality

Park was developed on a brownfield – land formerly used as railroads, warehouses, and stockyards. The soil needed remediation.

Water quality

Various methods of water and soil remediation were used.

Air quality

Park is located in Central Paris, therefore the air quality is typical for large urbanized areas. The presence of wetlands and open water reservoirs helps in lowering the temperature of the ground in hot weather (reduction of heat islands in the city, where most of the surface is hardened and quickly heats up).

Biodiversity

Almost 500 species of plants were planted in the park. Many wetlands and swamps were created, important from the point of view of protection against air, water and soil pollution, and promotion of biodiversity.

Forms of nature protection

Park was developed on a brownfield. There were no forms of nature protection applied to this site.

1.3. Universal accessibility

Park areas needed to be developed to promote universal accessibility.
There were obstacles to be negotiated e.g. crossing the traffic corridor.

1.4. ACCESS TO PARK

Distance to potential users

This park is located in the center of a new district. The new neighborhood was constructed around the park, which makes the park accessible within short walking distance from new apartments.

Public transport stops

The new metro line was built and one of the new stops was located next to the park. Regular bus lines also had stops in front of the main entrances to park.

Walkways to park

The streets leading to the park are extended by pedestrian paths inside the park. People are encouraged to cross the park while doing their daily duties. This park has no clear limits, instead, it is expanding with green corridors along all adjacent streets.

Fig. 4. Martin Luther King Park in Paris. Play areas for children. Photo: Monika Trojanowska

Fig. 5. Martin Luther King Park in Paris. Pavilion and platform build over highway crossing. Photo: Monika Trojanowska

2. PARK'S FUNCTIONAL PROGRAM

2.1. Psychological and physical regeneration

Natural Landscapes

Plants, especially planted at the perimeter of garden rooms succeed at times in hiding some of the surrounding high-rises, thus engendering a feel of the natural landscape. A part of the Park was planned to resemble a natural forest.

Green open space

There are multiple green open spaces of various sizes in the park. The largest is located in the center, smaller closer to the perimeter.

The place to rest in the sun and in the shade

Sitting benches are placed along the pathways in such manner that on a sunny day, it is always possible to find a place in the sun or in the shade. There are benches located next to trees which cast a shadow.

The place to rest in silence and solitude

The design encompasses smaller garden rooms, where users can sit in silence and solitude.

Possibility to observe other people

The elevated passage above the motorway creates a viewing platform, which makes it possible to observe the entire park area and adjacent streets. (fig. 5)

Possibility to observe animals

Carefully selected plants attract a variety of birds and colorful insects e.g. dragonflies.

2.2. Social Contacts Enhancement

Organization of events inside the park

Numerous events are organized in the park. The open green areas and wide pathways can accommodate stages, stands, and place for the participants.
The plaza next to the water reservoir serves as a natural gathering space for groups of people.

Gathering place for groups

Park is divided into smaller garden rooms, which can serve as places of gathering for groups. Some areas were designed for specific groups like children and teenagers, but there are also areas, which can be used by a variety of users.
The park was designed to welcome people with disabilities.

2.3. Physical Activity Promotion

There are play areas for different age groups from very small children to older kids and teenagers who can enjoy activities like roller-blading or basketball.
Sports grounds were designed for various disciplines. (fig. 4)

Sports and recreational infrastructure

Park offers a variety of sports infrastructure, creative play areas for various age groups.

Community gardens

Community gardens are located on parcels adjacent to the Park. They are open to visitors. There were plans for hortitherapy sessions for pensioners of EPHAD (Assisted Living Home) located next to the park.

2.4. Catering for basic needs

Safety and security

Park design is clear and legible. The entire area is cleaned regularly and well maintained.

Places to sit and rest

There are plenty of places to sit and rest located along the pathways and next to playgrounds.

Shelter

Park is located in the center of densely build neighborhood with numerous cafes, restaurants and shops, which can serve as shelter during adverse weather conditions. Inside the park Users can find shelter under the trees canopies or under the viewing platform. (fig. 5)

Restrooms

One of existing historic buildings was converted into public restrooms.

Drinking water

There is a pavilion with free drinking water – plain, sparkling or cooled. Water is pumped from artesian sources. (fig. 6)

Food

Food is easily available in stores, restaurants and cafes located inside the buildings which surround park.

Fig. 6. Martin Luther King Park in Paris. Pavilion with drinking water fountains. Photo: Monika Trojanowska

Fig. 7. Martin Luther King Park in Paris. Centrally located water pond. Photo: Monika Trojanowska

3. ORGANISATION OF SPACE AND FUNCTIONS

3.1. The park spatial composition follows the surrounding urban pattern

The urban streets in both directions north-south and east-west extend into the park in the form of planted promenades. The organization of the park creates legible and easy to understand pattern. The Park was built on a former railway site and the park maintains the overall initial horizontal topography. The Park stretches on both sides of a water tank – biotope basin located in the center. (fig. 7)

3.2. Architectural variety of urban environment

The architectural environment of the park is interesting and diversified. Buildings in the neighborhood were designed by different architects. General guidelines were created in the masterplan.

Focal points and landmarks

The overhead viewing platform is a focal point in the center of the Park. Additionally, the small wind turbine is a focal point in the part closer to Cabinet street.

Structure of interiors and connections

The park structure is clear and legible. The interiors are well connected

Long vistas (Extent)

The planted promenades extend into existing roads. This design offers long vistas.

Pathways with views

Walkways align with attractive ponds and garden interiors dedicated to themes of changing seasons. (fig. 8 and 9)

Invisible fragments of the scene (Vista engaging the imagination)

Park contains small secluded garden rooms.

Mystery, Fascination

The original design of - Jardin du rail – railroad garden containing reused original elements from the site (railroad tracks, etc.) can raise interest in the history of that place. Parts of the park designed to illustrate the theme of changing seasons offer interesting views and details.

Framed views

The design offers long vistas and views framed by plants.

Human scale

The distances between garden elements relate to the human scale and make this park comfortable and cozy.

3.3. Optimal level of complexity

The level of complexity of the design of garden rooms and features was subjectively assessed as optimal.

3.4. Natural surfaces

Natural permeable surfaces were used in the park. Majority of park surface is covered by plants.

3.5. Engaging features

There are numerous engaging features, for example, a variety of plants rich in color and textures as well as a variety of play equipment. Water basin and water jets are also amusing features.

Risk/Peril

The observation deck above the motorway could offer the "thrill of risk and peril", which can stimulate mental restoration. Observation from the distance of movement of people, water and even traffic can provide restoring experience [18].

Movement

Users can observe the calm and slow movement of water in the biotope basin and the invigorating movement of water jets.

3.6. Presence of Water

There is a biotope basin in the center of the Park. Along the promenade, a system of rain gardens harvests the rainwater. Water in the park Martin Luther King plays not only an aesthetic role but also an ecological role. In the park there are rain gardens which are filtering and purifying rainwater, underground retention reservoir located under a paved square, and an open pond (fig. 7). Rainwater from paved surfaces in the park flows into the so-called "Moist rain garden", where it is used for irrigation of moisture-loving plants. In the event of sudden precipitation, excess water flows from the rain gardens through overflows into the underground reservoir, from where it can be used to water the park during periods of drought. Biotope pool filters water from the Seine, which is transferred to the second pool, and then it is transported to an underground tank. The filtered water is mixed with water, which has been shed from a moist moat, stored and used for watering and cleaning of sidewalks during drought. The idea of the installation was to create an autonomous park when it comes to irrigation. If necessary, in dry months untreated water from the Seine river could be used. (About 40% of the park's needs for water for irrigation are met by rainwater, 60% of water for irrigation comes from the Seine). The water cycle supports energy from the mini-windmill in the park.

3.7. Sensory stimuli design

Sensory stimuli: Sight, Hearing, Touch

The sensory stimuli are provided by colorful planting, rich in textures. Hearing can be stimulated by shimmering plants and the sound of children at play.

Sensory stimuli: Smell

Numerous plants during spring and summer: e.g. magnolias, cherry trees, apple trees, dogwoods, and Judas trees spread their unique scents.

Fig. 8. Martin Luther King Park in Paris. Crossing the bridge over the ponds. Photo: Monika Trojanowska

Fig. 9. Martin Luther King Park in Paris. Elevated platform with shelter build over highway crossing. Photo: Monika Trojanowska

4. PLACEMAKING

4.1-2. Works of Art, Monuments in the park

One of the historic buildings – the forge inside the park was revitalized.

4.3. Historic places

Culture and connection to the past

The materials used inside the park – paving and railroad tracks provide a connection to the former use of this site -railroads, warehouses, and stockyards. (fig. 10)

4.4. Thematic gardens

There are various thematic gardens in this park, for example, *Jardin du rail* – railroad garden, or another garden illustrating changes of seasons.

4.5. Personalization

Personalization means allowing individual users to design and decorate fragments of public space. The community gardens with individual lots offer a possibility of personalization in this park. (fig. 11)

Fig. 10. Martin Luther King Park in Paris. Historic pavilions turned into restrooms. Photo: Monika Trojanowska

Fig. 11. Martin Luther King Park in Paris. Collective gardens. Photo: Monika Trojanowska

4.6. Animation of place

Many organized events animate the park space.

5. PURSUIT OF – SUSTAINABLE DEVELOPMENT

Various sustainable development principles were applied in the design of this Park: low maintenance, native plants, solar panels and wind turbines, reused materials for walkways, rainwater harvesting, energy and water resource management.

5.1. Green Infrastructure

Park promenades extend into adjacent streets creating green corridors of green infrastructure.

5.2. Parks of Second (New) Generation

Park can be described as the park of a second (new) generation because it was developed on a brownfield and multiple sustainable development principles were applied.

5.3. Biodiversity protection.

Native animals

Multiple solutions related to biodiversity protection were observed, for example, secluded fenced gardens for local animals and hotels for insects.

Native plants

Low-maintenance regional plants and shrubs were planted.

Natural maintenance methods

Applied solutions include low-maintenance regional plants and shrubs, solar panels, wind turbines, rainwater recycling, waste management, etc.

5.4. Sustainable water management

Rainwater infiltration

Rain gardens and sustainable drainage solutions were created inside the park.

Irrigation with non-potable water

Rainwater is harvested, stored in underground tanks, and used for irrigation. Rainwater usually fulfills all watering needs within the park for 11 months during the year. Sustainable principles of watering - minimum discharge to the sewer (unless exceptional rains), collection of rainwater, and recycling of water are applied.

Park in a Flood risk zone

Not applicable.

5.5. Urban metabolism

Old materials from the site were reused. All waste is segregated inside the park. Pneumatic waste collection is used in the neighborhood.

5.6. Ecological energy sources

The solar panels are placed on the roof of the forge building to produce energy. Low power equipment is used for park lighting.

The pumps for the recirculation of water in the irrigation system use the energy produced by a small wind turbine located inside the park.

3. Discussion of results

During the study, this park was assessed to have all the attributes and features listed in the Universal Pattern of Design for Therapeutic Parks. It was also observed that it was always full of users, although there were other parks available within short walking distance in the adjacent neighborhood. The overall results of this park design and functioning were estimated as satisfactory in all categories. This tool was used for the assessment of ten popular public parks in Bydgoszcz [12]. Their results were satisfactory and ranged from 41 to 48 for Leśny Park Kultury u Wypoczynku w Myślęcinku, a vast forest park with numerous recreational infrastructure facilities which cover over 830 ha. The fact that a similar number of therapeutic attributes was reunited in smaller space does not mean that smaller parks can replace large scale open green areas. However, the same results can be interpreted as a possibility to provide a satisfactory and health-affirming place to individuals in a situation of a limited number of users. The capacity to accommodate a larger number of people and guarantee satisfactory use of therapeutic qualities requires larger areas.

4. Conclusions

The health-affirming urban places are an invaluable asset and therefore should be designed and implemented wherever possible. The therapeutic parks, which reunite all the qualities relying on therapeutic landscapes and health affirming places should be created in every neighborhood in order to promote human health.

The Universal Pattern of Design for Therapeutic Parks is a ready-to-use tool for evaluating the therapeutic potential of existing public parks. It can be used to assess the therapeutic qualities of parks and identify attributes that are missing. The identified limitation of the Universal Pattern derives from the subjectivity of individual perception. The subjectivism of assessment could be mitigated with a more detailed description of a given attribute. Another option is to employ various researchers to perform the assessment, compare and discuss the results.

This tool is relatively easy to use and therefore can be recommended to professional designers but also social activists who feel responsible for their neighborhood and promotion of human health

Table 1. Universal pattern of design for health affirming urban places

UNIVERSAL PATTERN OF DESIGN FOR HEALTH-AFFIRMING URBAN PLACES					
UNIVERSAL PATTERN OF DESIGN FOR THERAPEUTIC PARKS					6. ACCESS TO PARK
1. UNIVERSAL DESIGN	2. PARK'S FUNCTIONAL PROGRAM	3. ORGANIZATION OF SPACE AND FUNCTIONS	4. PLACEMAKING	5. SUSTAINABILITY	
1.1. Place Area Location Surrounding urban pattern **1.2. Environmental characteristics** Soil quality Water quality Air quality Biodiversity Forms of nature protection **1.3. Universal accessibility** (addressing need of people with disabilities) **1.4. Access to park** Distance to potential users Public transport stops Walkways to park	**2.1. Psychological and physical regeneration** Natural Landscapes Green open space Place to rest in the sun and in the shade Place to rest in silence and solitude Possibility to observe other people Possibility to observe animals **2.2. Social Contacts Enhancement** Organization of events inside the park Gathering place for groups **2.3. Physical Activity Promotion** Sports and recreational infrastructure Community gardens **2.4. Catering for basic needs** Safety and security (presence of guards, cleanness, maintenance, etc.) Places to sit and rest Shelter Restrooms Drinking water Food (possibility to buy food in the park or close vicinities)	**3.1. The park spatial composition follows the surrounding urban pattern** **3.2. Architectural variety of urban environment** Focal points and landmarks Structure of interiors and connections Long vistas (Extent) Pathways with views Invisible fragments of the scene (Vista engaging the imagination) Mystery, Fascination Framed views Human scale **3.3. Optimal level of complexity** **3.4. Natural surfaces** **3.5. Engaging features** Risk/Peril Movement **3.6. Presence of Water** **3.7. Sensory stimuli design** Sensory stimuli: Sight Sensory stimuli: Hearing Sensory stimuli: Smell Sensory stimuli: Touch Sensory stimuli: Taste Sensory path	**4.1. Works of Art** **4.2. Monuments in the park** **4.3. Historic places** Culture and connection to the past **4.4. Thematic gardens** **4.5. Personalization** **4.6. Animation of place**	**5.1. Green Infrastructure** **5.2. Parks of Second (New) Generation** **5.3. Biodiversity protection** Part of park not-available to visitors Native plants Native animals Natural maintenance methods **5.4. Sustainable water management** Rainwater infiltration Irrigation with non-potable water Park in a flood risk zone **5.5. Urban metabolism** **5.6. Ecological energy sources**	**6.1. Sidewalk Infrastructure**- Width of sidewalk Evenness of surface Lack of obstructions Slope Sufficient drainage **6.2. General conditions**: Maintenance Overall aesthetics Street art Sufficient seating Perceived safety Buffering from traffic Street activities Vacant lots **6.3. Traffic** Speed Volume Number and safety of crossings Stop signs On-street parking **6.4. User Experience** Air quality Noise level Sufficient lighting Sunshine and shade Transparency of ground floors of building

Table 2. *Assessment of health-affirming urban place – ZAC Clichy Batignolles* The rough binary assessment of therapeutic qualities of Martin Luther King Park

1. UNIVERSAL DESIGN		**3.3. Optimal level of complexity**	1
1.1. Place		**3.4. Natural surfaces**	1
Area, approximately	10 ha	**3.5. Engaging features**	
Location	city centre	Risk/Peril	1
Surrounding urban pattern	dense urban tissue	Movement	1
1.2. Environmental characteristics		**3.6. Presence of Water**	1
Soil quality	brownfield	**3.7. Sensory stimuli design**	
Water quality		Sensory stimuli: Sight	1
Air quality		Sensory stimuli: Hearing	1
Biodiversity	rich in species	Sensory stimuli: Smell	1
Forms of nature protection	no	Sensory stimuli: Touch	1
1.3. Universal accessibility	accessible	Sensory stimuli: Taste	0
1.4. Access to park		Sensory path	0
Distance to potential users	less than 500m	**4. PLACEMAKING**	
Public transport stops	yes	**4.1. Works of Art**	0
Walkways to park	multiples	**4.2. Monuments in the park**	0
2. PARK'S FUNCTIONAL PROGRAM		**4.3. Historic places**	
2.1. Psychological and physical regeneration		Culture and connection to the past	1
Natural Landscapes	1	**4.4. Thematic gardens**	1
Green open space	1	**4.5. Personalization**	1
Place to rest in the sun and in the shade	1	**4.6. Animation of place**	1
Place to rest in silence and solitude	1	**5. PURSUIT OF -SUSTAINABLE DEVELOPMENT**	
Possibility to observe other people	1	**5.1. Green Infrastructure**	1
Possibility to observe animals	1	**5.2. Parks of Second (New) Generation**	1
2.2. Social Contacts Enhancement		**5.3. Biodiversity protection**	
Organization of events inside the park	1	Part of park not-available to visitors	1
Gathering place for groups	1	Native plants	1
2.3. Physical Activity Promotion		Native animals	1
Sports and recreational infrastructure	1	Natural maintenance methods	1
Community gardens	1	**5.4. Sustainable water management**	
2.4. Catering for basic needs		Rainwater infiltration	1
Safety and security	1	Irrigation with non-potable water	1
Places to sit and rest	1	Park in a flood risk zone	no
Shelter	1	**5.5. Urban metabolism**	1
Restrooms	1	**5.6. Ecological energy sources**	1
Drinking water	1	**TOTAL**	**48**
Food	0		
3. ORGANISATION OF SPACE AND FUNCTIONS			
3.1. The park spatial composition follows the surrounding urban pattern	1		
3.2. Architectural variety of urban environment	1		
Focal points and landmarks	1		
Structure of interiors and connections	1		
Long vistas (Extent)	1		
Pathways with views	1		
Invisible fragments of the scene (Vista engaging the imagination)	1		
Mystery, Fascination	1		
Framed views	1		
Human scale	1		

Table 3. *Assessment of health-affirming urban place – ZAC Clichy Batignolles Assesment of* ACCESS TO PARK category

STREETS	Rue Cardinet	Rue Bernard Buffet	Rue Gillbrt Cesbron	Rue Mstislav Rostopovitch	Boulevard Berthier	Allee Colette Heilbronner
6.1. Sidewalk Infrastructure						
Width of sidewalk	good	good	good	good	good	good
Evenness of surface	good	good	good	good	good	good
Lack of obstructions	lack of obstructions	lack of obstructions	lack of obstructions	lack of obstructions	lack of obstructions	lack of obstructions
Slope	not important	partially sloped	not important	not important	not important	important, accessible to wheelchairs
Sufficient drainage	sufficient	sufficient	sufficient	sufficient	sufficient	sufficient
6.2. General conditions						
Maintenance	good	good	good	good	good	good
Overall aesthetics	good	good	good	good	good	good
Street art	no	no	no	no	no	no
Sufficient seating	yes	no	yes – private cafes	no	no	no
Perceived safety	good	good	good	good	good	good
Road noise	moderate	moderate, one way traffic	moderate, one way traffic	moderate	moderate	moderate
Buffering from traffic	buffering with greenery on one side	partially with greenery	buffering with greenery	buffering with greenery	buffering with greenery	
Street activities	no	no	no	no	no	
Vacant lots	no	no	no	no	yes	
6.3. Traffic						
Speed	moderate	slow	slow	slow	slow	
Volume	important, main road	one way	one way	moderate	important, main road	little
Number and safety of crossings	street lights, safe	safe crossings	safe crossings	safe crossings	safe crossings	safe crossings
Stop signs	no	no	no	no	no	no
On-street parking	yes	prohibited	yes	yes	yes	no
6.4. User Experience						
Air quality	average	average	average	average	average	average
Noise level	moderate	moderate	moderate	moderate	moderate	moderate
Sufficient lighting	yes	yes	yes	yes	yes	yes
Sunshine and shade	trees on one side	trees provide shade	trees provide shade	trees provide shade	trees provide shade	trees provide shade
Transparency of ground floors of building	on one side	on one side, transparent fencing on other side	on both sides	partially on both sides	on both sides	park on one side, blvrd Berthier on other side

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Przesłano do redakcji: 6.02.2019 r.

CZASOPISMO INŻYNIERII LĄDOWEJ, ŚRODOWISKA I ARCHITEKTURY
JOURNAL OF CIVIL ENGINEERING, ENVIRONMENT AND ARCHITECTURE
JCEEA, t. XXXVI, z. 66 (2/19), kwiecień-czerwiec 2019, s. 65-75, DOI:10.7862/rb.2019.12

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BUILDING INFORMATION MODELLING AND COPYRIGHT

Building Information Modeling (BIM) translated directly into Polish means modeling information about a building. BIM is used in the planning, design, management and implementation of construction, and – ultimately – in building management. In addition, BIM allows simultaneous cooperation of many people on one project. However, the question arises whether models created using this technology are protected by law. One of the most important issues related to BIM, and particularly models created using this technology, is the protection of copyright, which is why these issues are discussed in more detail in this article.

Keywords: real estate, BIM, proptech, copyrights, work

1. Introduction

In the construction sector, many investments end up failing to meet deadlines or exceed the costs included in the cost estimate. One of the problems is the incorrect organization of the construction investment process. The current approach brings the possibility of failure caused by the cooperation of independent design and implementation units. As shown by the CMAA Owners Survey 2005, CMAA Industry Report 2007, approx. 30% of the investments carried out were subject to the risk of exceeding the schedules or cost estimates. The research also shows that an estimated 1/3 of materials ordered for construction purposes was wasted, and 10% of the total investment costs included errors in orders. To avoid incurring the above-mentioned costs, the stages of construction project implementation should be connected. Such an integration of the design stage with the implementation stage is called the Integrated Project Delivery (IPD)[1]. Globally, among others in the United States, the IPD contracting model is used, based on the contract signed by several entities (in addition to the investor and the contractor also by the designer, architect and key subcontractors). In Poland, such contracts do not yet exist. Moreover, it is worth noting that Polish construction sector is flooded with paper

[1] M. Drzazga, *BIM – zapis informacji o przedsięwzięciu budowlanym (projektowanie 5D)*, "Przegląd Budowlany" 9/2016, p. 33.

documentation. Verification of the project in terms of compliance with applicable regulations or technical and economic assumptions turns out to be tedious work and the cause of conflict between the investor and the architect, as well as between the constructor and the contractor. The optimization of the entire construction process as well as the integration of all its participants can be ensured thanks to digital technology – Building Information Modeling (BIM)[2].

Many people think that BIM is a development of CAD (Computer Aided Design, also Computer Aided Drafting) methods. The importance of BIM, however, goes far beyond the very process of project development. While the goal of CAD was to improve the preparation of documentation, the goal of BIM is to computerize the process of the implementation of investment[3]. The term "BIM" was popularised in 2002 by construction analyst Jerry Laiserin, who used it to describe virtual design and building management in all its life cycles. Some say BIM is about the design software. Others claim that this is a virtual model of the building. For some, it is a process or an organised database dedicated to the building. BIM can also be called a digital description of physical and functional properties of buildings, serving as a source of knowledge and data about the object. BIM information is the basis for data exchange between the participants of the investment process and facilitate the cooperation of the teams implementing the undertaking[4]. Finally, BIM can also be a database about a building that is developed throughout its entire life cycle. Created for this purpose and updated as-built model, it can be used as a database informing about a given object, to help e.g. in planning maintenance or renovation works or in the current analysis of the condition of the building[5]. Therefore, understanding of the "BIM" term is not uniform. Without contradicting the multifaceted nature of BIM, it should be emphasized that this technology has changed, among others, the way of creating construction documentation.

In the United States, all public investments at the design and implementation stage must now be handled with BIM, in the UK it is used more and more often. Unfortunately, in Poland, BIM is not yet widely used. Therefore, the term "BIM" has not been defined in any of the acts of in Polish law. However, it should be noted that in accordance with art. 10e of the Public Procurement Law, in the case of works contracts or tenders, the contracting authority may require the use of electronic data modeling tools for construction

[2] *Optymalizacja procesu projektowania budynku – technologia BIM*, https://swiat-aluminium.pl/aktualnosci/architektura/438-optymalizacja-procesu-projektowania-budynku-%E2%80%93-technologia-bim.html, 12.08.2015 r. (accessed on 7.05.2019).
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[4] *Dictionary of terms related to BIM*, http://bim4u.eu/slownik (accessed on 10.04.2019).
[5] E. Wiktorowska, *Art. 10(e)*, *Prawo zamówień publicznych. Komentarz aktualizowany. system informacji prawnej LEX*, 2019.

data or similar[6] and BIM actually is such a tool[7]. The Polish legislator allows the use of BIM tools in public procurement, but in none of the legal acts determines how the resulting models could be protected. Undoubtedly, one of the most important issues that should be analysed is the protection of copyrights of models created by BIM. It is worth considering whether models created using this technology are covered by copyright.

2. Sources of law

Considerations about the copyright should start with identifying the sources of law. Copyright law has been regulated at the international, European and national level.

At the international level, one must consider the regulations contained in the Berne Convention for the Protection of Literary and Artistic Works[8]. This is one of the first agreements on respecting copyright. Initially, in 1886, 10 European countries signed the convention in order to unify certain rules on copyright. Poland acceded to the Berne Convention on January 28, 1920. The Convention is based on two basic principles: the principle of minimum protection (signatories must ensure in national domestic law such copyright protection as provided for in the Convention) and assimilation principle (the creator from another country must be treated equally with citizens of a given member state). According to the Berne Convention, in principle, the minimum duration of protection covers the life of the author and 50 years after his / her death. Another important act at the international level is the universal TRIPS copyright convention[9], which was developed by UNESCO. Like the Berne Convention, it contains the principle of mutual respect of rights and prohibits any discrimination against foreign authors. You also need to consider the copyright laws included in the World Intellectual Property Organization Copyright Treaty[10]. It refers to the protection of digital content, databases and computer programs.

At the European level, on the other hand, the Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonization of certain aspects of copyright and related rights in the information society should be highlighted. The aims of the directive were to harmonize copyright protection in the European Union and to adapt the level of protection to the

[6] Journal of Laws of 2018, item 1986 as amended.
[7] E. Wiktorowska, *Art. 10(e)*, *op. cit.*
[8] Journal of Laws of 1935, No. 84 item 515.
[9] Agreement on Trade-Related Aspects of Intellectual Property Rights, www.wto.org/english/ /docs_e/legal_e/27-trips.pdf (accessed on 15.03.2019).
[10] Journal of Laws of 2005, No. 3, item 12.

realities of using digital works[11]. The Directive on Copyright in the Digital Single Market, formally the Directive (EU) 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market and amending Directives 96/9/EC and 2001/29/EC is a European Union (EU) directive came into force on June 6, 2019[12]. It aims to modify the copyright law in the European Union so that it meets the requirements of the digital age. These changes are made as part of the European Commission's project. The goals include creating a single market in the European Union and enabling more effective competition with entities from other regions, e.g. the USA. The effects will probably be visible after a few years of their application in practice.

In Poland, works and objects covered by related rights are protected primarily by the provisions of the Act on Copyright and Related Rights[13]. This act will be the subject of further considerations regarding the possibility of ensuring copyright protection of the models created by BIM.

3. The term "work" according to the Act on Copyright and Related Rights

The subject matter of the copyright is the work. The work is a basic, fundamental institution of copyright, as well as the reason and justification for the creation and separation of this area of private law[14]. It is an intangible legal good, which should be distinguished from the material object (material medium, also referred to as *corpus mechanicum*), on which it is usually fixed[15]. The article 1, para. 1 of the Act on Copyright and Related Rights defines what the work is. Work is every manifestation of creative activity of an individual character, established in any form, regardless of the value, purpose and manner of expression. The work is subject to copyright from the moment it is determined, even if it has an unfinished form. The subject scope of copyright protection set out in the aforementioned definition is described in art. 1 para. 2 of the Act on Copyright and Related Rights by listing basic categories of works. The listing is exemplary and not exhaustive, which means that other characters of the song may also appear on the market, as long as they meet the

[11] L 130/92, https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:32019L0790&from=ET (accessd on 27.11.2019).
[12] *Conclusion. Directive of the European Parliament and Council on copyright in the Digital Single Market*, https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:52016PC0593&from=EN (accessed on 15.03.2019).
[13] Journal of Laws of 2018, item 1191 as amended.
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conditions set out in the definition of the work. The basic categories of works include architectural, architectural-urban and urban works.

In the context of considerations devoted to the definition of a work, the elements determining its existence are also important. The three following premises should be met jointly: there must be an element of creativity, individual character and it has to be fixed in any form.

According to the current synthetic definition, work is a manifestation of creative activity. Creative activity thus becomes the key to understanding the notion of "work". The use of the term "creativity", as is apparent from the wording of the provision, in its functional meaning may seem a bit misleading. After all it is not about the creation elements that would manifest themselves in the process of creating a work, but as a result of this activity[16]. Undoubtedly, to talk about creativity, there must be a creative element. In this case – what is important in the context of BIM – the effect resulting from routine and template activities will not meet these criteria. Polish courts have repeatedly expressed themselves on this issue. According to the case law, if the technical documentation is on the verge of copyright protection, it is in principle granted copyright protection[17]. In practice, proprietary protection will cover primarily untypical and innovative solutions – in the scope of both the construction itself (e.g. in the date of preparation of this article, a lot of space is devoted to an office building using wooden construction) and individual industries (especially when using building materials based on on so-called unit admission). On the other hand, it may be difficult in practice to capture the creative element in the situation of template solutions.

Another premise that regulates the definition of work is its individual character. In Polish jurisprudence and doctrine there is a lack of agreement on the understanding of the premise of individual character. Mostly it refers to the result of human activity, it is connected with the concept of originality, novelty or the mark of a personal creator[18]. The work should have a unique character.

The last premise is the possibility to determine the work in any form in such a way that third parties can be familiar with it, and therefore also in electronic form. At the same time, the so-called determination has to be distinguished from the fixing of the work. The determination consists in the fact that any recipient other than the artist himself / herself may get acquainted with the work. In turn, the fixation is based on the fact that the work is replaced by a form that allows any number of people to be familiar with it at any time. It is worth noting that it is enough for a work to have been determined to gain protection, but it is not necessary to be fixed.

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[16] M.R. Sarbiński, *Art. 1*, *op. cit.*

[17] VI ACa 1200/14, LEX nr 1936794.

[18] M.J. Stępień, *Indywidualny charakter utworu jako przesłanka ochrony prawnoautorskiej dzieła technicznego*, "Acta Iuris Stetinensis" 2(18)/2017, p. 341.

4. The creator and his / her personal and proprietary rights

The creator is the person who created the particular work. Creator status may be granted to natural persons due to the fact that they may undertake creative activities. Already from the statutory definition of the work, it appears that it is a manifestation of a personal act of creativity, and thus the creator cannot be replaced in this matter by another person. Creating a work is an event resulting with specific legal consequences. They can arise for the benefit of any natural person. According to art. 8 of the Civil Code, everyone has legal capacity (the ability to be a subject of rights and duties)[19]. Therefore, it is not required to achieve a certain age, creation awareness or the psychophysical state of the creator to be covered by copyright[20].

Undoubtedly, the creator of, for example, architectural and construction project will be an architect, and in the case of an industry project – a specific designer. Article 8 para. 1 of the Act on Copyright and Related Rights expresses the basic principle of copyright, according to which the original author is the subject of the right. This principle covers both proprietary personal rights and proprietary copyrights. Any exceptions to this rule may not result from the will of the parties, it can be established only by a legal provision. Personal rights are not defined in any legal act, although the catalog of personal rights is mentioned in art. 23 of the Civil Code. The Act on Copyright and Related Rights also regulates the issue of personal rights (art. 16). Personal goods should be understood as the bond of the creator and the work, but they are not transferable and are not subject to inheritance. The legislator lists as personal rights the right to authorship, the right to be named, etc. In turn, proprietary copyrights are regulated in art. 17 of the Act on Copyright and Related Rights. Unless the act provides otherwise, the author has the exclusive right to use the work and dispose of it in all fields of exploitation and to collect remuneration for using the work.

The proprietary copyrights may be transferred or be contractually made available for use (licensed). The duration of copyright has been regulated in detail in art. 36, 37 and 39 of the Copyright and Related Rights Act[21]. The proprietary copyrights belonging originally to the creator (in most cases) expire after 70 years counted from his death, and in the case of co-authored works – from the death of the last co-creator who survived the others. It is different when the author hid under a pseudonym (actual, not artistic) or asked for anonymity when spreading the work (composition, words) – the 70 years counts then from the date of the first release of the work to the public. However, if at that time the author reveals his / her identity, this period counts from the

[19] Journal of Laws of 2018, item 1025 as amended.
[20] M. Wiśniewska, *Podmiot prawa autorskiego – twórca*, https://lexplay.pl/artykul/prawo_autorskie/ /Podmiot-prawa-autorskiego-tworca (accessed on 20.03.2019).
[21] Journal of Laws of 2018, item 1191 as amended.

creator's death. In the course of being an anonymous author or hiding under a pseudonym in the exercise of copyright law, he / she is replaced by the publisher, producer or competent organization of collective copyright management, e.g. in Poland the ZPAP (artists' rights) or SARP (architect's rights)[22].

5. Models created in BIM – how to protect them?

There is an ongoing discussion in the world about the need to protect as copyrighted works models made in multidimensional technologies. Currently, there are no regulations that would precisely address this issue. In my opinion, some kind of protection exists, but it should be noted that there is a lack of specific regulations relating to multidimensional projects.

In the understanding of copyright, work is a product of the human intellect (the creation of the creator). The forms generated by the forces of nature and animals are not protected. It is assumed that if the creation of a work includes using tools, machines or other technical means, the author is the one who determines their use and method of work[23]. From a legal point of view, CAD and BIM programs are tools that improve the design process of a building. The author will be the one who will determine the use of a given program. As E. Czernik emphasizes, structures designed using these programs do not differ from those that are created manually[24]. This sentence deserves approval, especially in the context of the analysis of the protection of projects created on the basis of BIM and the issue of copyright protection. Multidimensional models could therefore be subject to similar protection as hand-made models.

However, when creating projects in BIM, it is difficult to capture a creative element that comes from a specific person. In practice, it is extremely difficult. Determining who is the creator of a given element requires analysing specific factual circumstances. From the very beginning it is worth thinking about regulating all issues through the use of contract instruments. People who create a specific project in BIM should determine to whom the individual elements of this project belong. The right to decide on the form of the work belongs to the author. If the author decides to transfer his / her proprietary copyrights, he / she should remember to transfer (or not to transfer) derivative rights (the right to change, alterations). If the derivative rights are not transferred, the content of the work should not be changed after the transfer. The author should agree for each modification.

When concluding contracts in Poland, it is important to remember about the principle of freedom of contract. According to art. 353 as amended 1 of the Civil Code, contracting parties may establish a legal relationship at their own

[22] *Duration of copyright and related proprietary rights*, https://zaiks.org.pl/171,154,6_ czas_ _trwania_autorskich_i_pokrewnych_praw_majatkowych (accessed on 20.03.2019).
[23] A. Binder, F. Kosterhon, *Urheberrecht für Architekten und Ingenieure*, München 2003, s. 21.
[24] *Ibidem.*

discretion, as long as its content or purpose does not oppose the property (nature) of the relationship, the act or the rules of social coexistence. Interpretation of the nature of a legal relationship is a characteristic element of freedom of contract. As also unnamed contracts can have their nature. In such a case, it is difficult to talk about contradictions with the act, as there are no provisions regulating these contracts. The parties may establish a legal relationship at their own discretion. As a rule, this allows you to shape the content of contracts to any degree. Contracts between the contractor and the investor should regulate the transfer of proprietary copyrights or licensing. It is not possible to transfer personal rights (it is possible, however to oblige not to exercise copyrights). In addition to the transfer of proprietary rights, it is important to remember about the regulations on derivative rights, such as adaptation and modification.

Imprecise or nonexisting contract provision may result in copyright infringement. We face copyright infringement each time, when an unauthorized entity enters the copyright of the authorized person. Copyright infringement may occur directly or indirectly. A direct infringement is committed by the perpetrator himself / herself, by entering the scope of the monopoly of the rightholder. It takes the form of e.g. assigning oneself someone else's work in its original version (art. 115 para. 1 of the Act on Copyright and Related Rights) or the reproduction and dissemination of the work in the original version without the consent of the authorized person (art. 117 para. 1 of the Act on Copyright and Related Rights). It is also possible to conduct an indirect infringement of rights. For example, the civil liability for infringement of copyright, in addition to the perpetrator, is also borne by: a helper, instigator and a person who consciously benefited from the damage caused to the other (art. 422 of the Civil Code). In addition, according to the Civil Code, a third party may be liable if the perpetrator cannot be held guilty because of age (art. 426 of the Civil Code – minors up to 13 years old) or liability cannot be attributed to him / her due to being in a state that disables sanity (art. 425 of the Civil Code).

In Polish civil law, two types of civil liability can be distinguished, namely tort liability and contractual liability (the division resulting from the source of liability). We can speak of tort liability when the damage caused to one entity by the other is an independent source of the obligatory relationship between them, regardless of whether the two entities previously had any legal relationship. In turn, contractual liability is presented in the Polish Civil Code (*ex contractu*) in art. 471. If the debtor, in spite of the existing legal relationship, does not fulfill his / her obligation, the creditor is entitled to a claim for damages that has resulted from the non-performance or improper performance of the obligation[25].

[25] J. Józefczyk, *Odpowiedzialność deliktowa a odpowiedzialność kontraktowa*, https://mojafirma.infor.pl/umowy-w-firmie/abc-umow/294929,Odpowiedzialnosc-deliktowa-a-odpowiedzialnosc-kontraktowa.html, 12.09.2014 r. (accesed on 10.04.2019).

This is the case, for example, of a situation where the author does not grant derivative rights to the contractor, but the contractor nevertheless modifies the work.

In some cases, apart from the civil liability, the copyright infringement is also punishable by criminal liability. The misappropriation or misleading about the authorship of all or part of someone else's work or artistic performance, is punishable with a fine, restriction of liberty or deprivation of liberty for up to three years. The same penalty is imposed on the one who disseminates the work in the original version or in the form of a compilation without publicly mentioning the name or pseudonym of the creator or is publicly distorting such a work. A fine, restriction of liberty or imprisonment is also imposed on a person who, without the right or against its conditions, disseminates someone's work in the original version or in the form of a study. It is therefore worth specifying the legal relations precisely at the very beginning of creating building models using the BIM tools. The absence in the contract of precise provisions regarding copyright issues may result in the use of the work in a manner that violates these rights.

6. Conclusions

The issue of copyright for works performed in BIM is undoubtedly problematic. Despite the existence of many regulations regarding copyright, there are currently no legal regulations in Poland that would directly define the protection of such works. It would be reasonable on the part of the legislator – *de lege ferenda* – to introduce specific solutions relating to the protection of multidimensional projects. It may be troublesome to combine different solutions in BIM as a result of the work of different people (although this may apply not only to the same architectural project, but also to the combination of various projects and industry solutions). Moreover, in practice the situation may be complicated by the difficulty in separating creative solutions from typical, commonly accepted solutions. Therefore, it should be assessed individually whether a given model can constitute a work within the meaning of the Act on Copyright and Related Rights. For models created using BIM, the challenge would be to capture the creative element.

For many years there have been discussions about the evaluation of which designer's work can constitute an architectural work and which not. This problem is even more visible in the case of projects created in BIM. Project members should clearly regulate at the very best beginning all the copyright issues in their respective contracts. Depending on the type of project (*build*, *design&build*) the contracts between the investor and the general contractor, as well as the contracts between the investor and the architect, should include provisions regarding copyright. The appropriate regulation in contracts regarding this issue should be each time considered. The market definitely makes much more use of

the possibilities that BIM offers from the technical side than of the legal possibilites. Currently in Poland, we are far from composing multilateral contracts with innovative clauses, like those created by the American Chamber of Architects[26]. The implementation of Integrated Project Delivery contracts could be on of possible solutions. The greatest strength of the IPD is the ability to compromise, work in accordance with clearly defined rules of the game and using the strengths of all players[27].

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[2] Binder, F. Kosterhon, *Urheberrecht für Architekten und Ingenieure*, München 2003.

[3] Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society.

[4] Directive of the European Parliament and Council on copyright in the Digital Single Market.

[5] E. Wiktorowska, *Prawo zamówień publicznych. Komentarz aktualizowany. system informacji prawnej LEX*, 2019.

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[10] Berne Convention for the Protection of Literary and Artistic Works of September 9, 1886, reviewed in Berlin on November 13, 1908 and Rome on June 2, 1928 (ratified in accordance with the Law of 5 March 1934), Journal of Laws of 1935, No. 84 item 515.

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[26] K. Majewski, K. Stolarski, *Building Information Modeling (BIM) – kwestie prawne i praktyczne. Zamawiający 2018/30/7-9*, LEX.

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[14] M. R. Sarbiński, *Prawo autorskie. Komentarz do wybranych przepisów*, Wydawnictwo Prawnicze LexisNexis, 2014.

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[16] Agreement on Trade-Related Aspects of Intellectual Property Rights, TRIPS.

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[18] Act of 23 April 1964 – Civil Code, Journal of Laws of 2018 item 1025 as amended.

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[21] W. Szymanik, *Ci, którzy pierwsi wdrożą BIM, wygrają*, www.inzynierbudownictwa.pl/ /technika,materialy_i_technologie,artykul,ci_ktorzy_pierwsi_wdroza_bim_wygraja,10566, 2.01.2018 r. (accessed on: 29.04.2019).

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Przesłano do redakcji: 10.09.2019 r.

Additional information

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